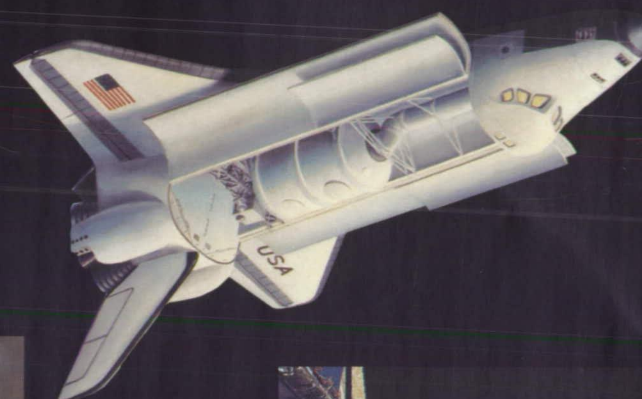
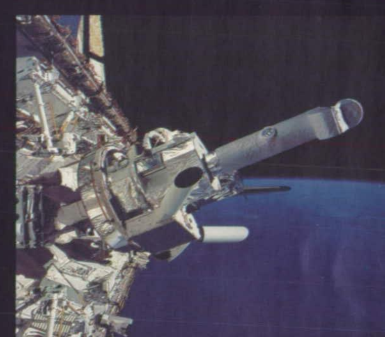
STS Investigators' Guide





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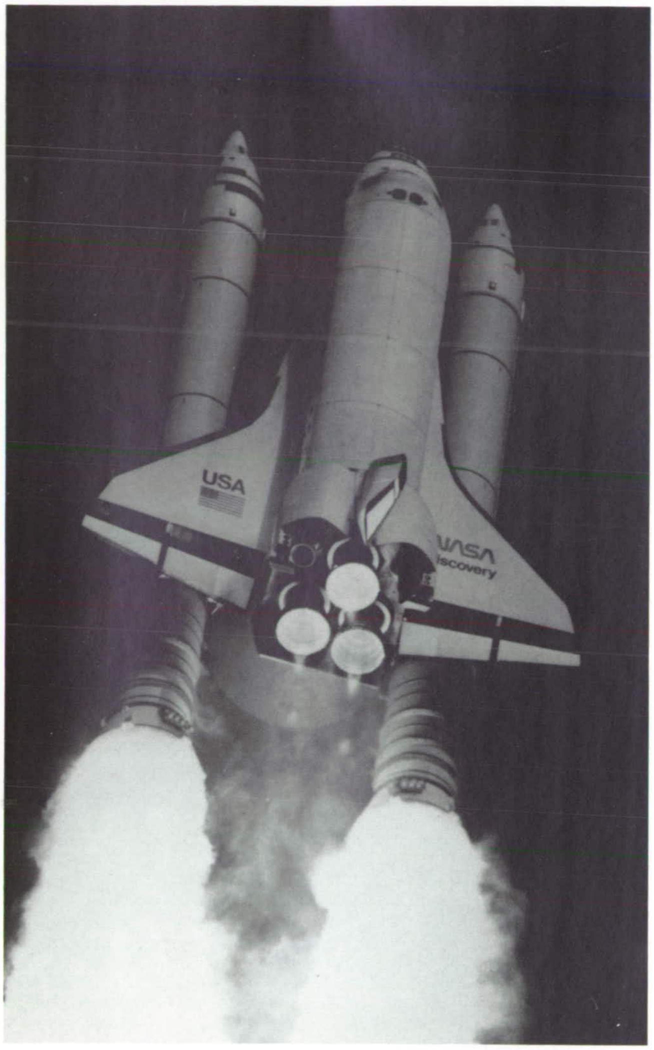


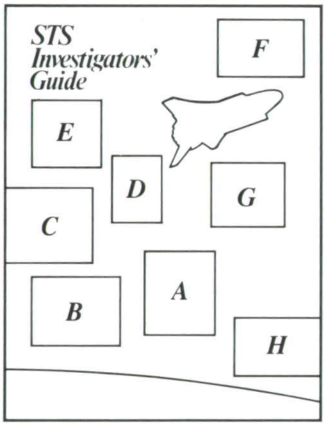
STS Investigators' Guide

SPACE SHUTTLE

NASA
National Aeronautics and
Space Administration

October, 1989

George C. Marshall Space Flight Center



On the Cover:

A. *A scientist assembles an instrument used to manufacture the first space-made product that was sold commercially – small latex spheres for calibration purposes.*

B. *Integrated payloads are placed inside the Shuttle, and interfaces are tested.*

C. *To check out instruments and train crews, experiments are tested aboard NASA's KC-135 aircraft which is flown in a parabolic pattern to provide brief periods of weightlessness.*

D. *Shuttle launch*

E. *Lightweight carriers fit inside the Shuttle, providing platforms for scientific instruments.*

F. *Scientists collect data during a Shuttle mission.*

G. *An instrument pointing system inside the Shuttle payload bay aims telescopes at the sun.*

H. *Shuttle landing*

Foreword

THIS DOCUMENT was developed by Teledyne Brown Engineering under the direction of the Payload Projects Office, Marshall Space Flight Center. It is a guide for anyone who is interested in using the Space Transportation System (STS) for conducting science and technology research. It provides information on what onboard accommodations are available, how to arrange to fly an experiment, and what to expect once preparations for the flight are under way.

Further information may be obtained from:

Payload Projects Office
NASA/Marshall Space Flight Center
Code JA01
Marshall Space Flight Center, AL 35804
Telephone 205-544-5416

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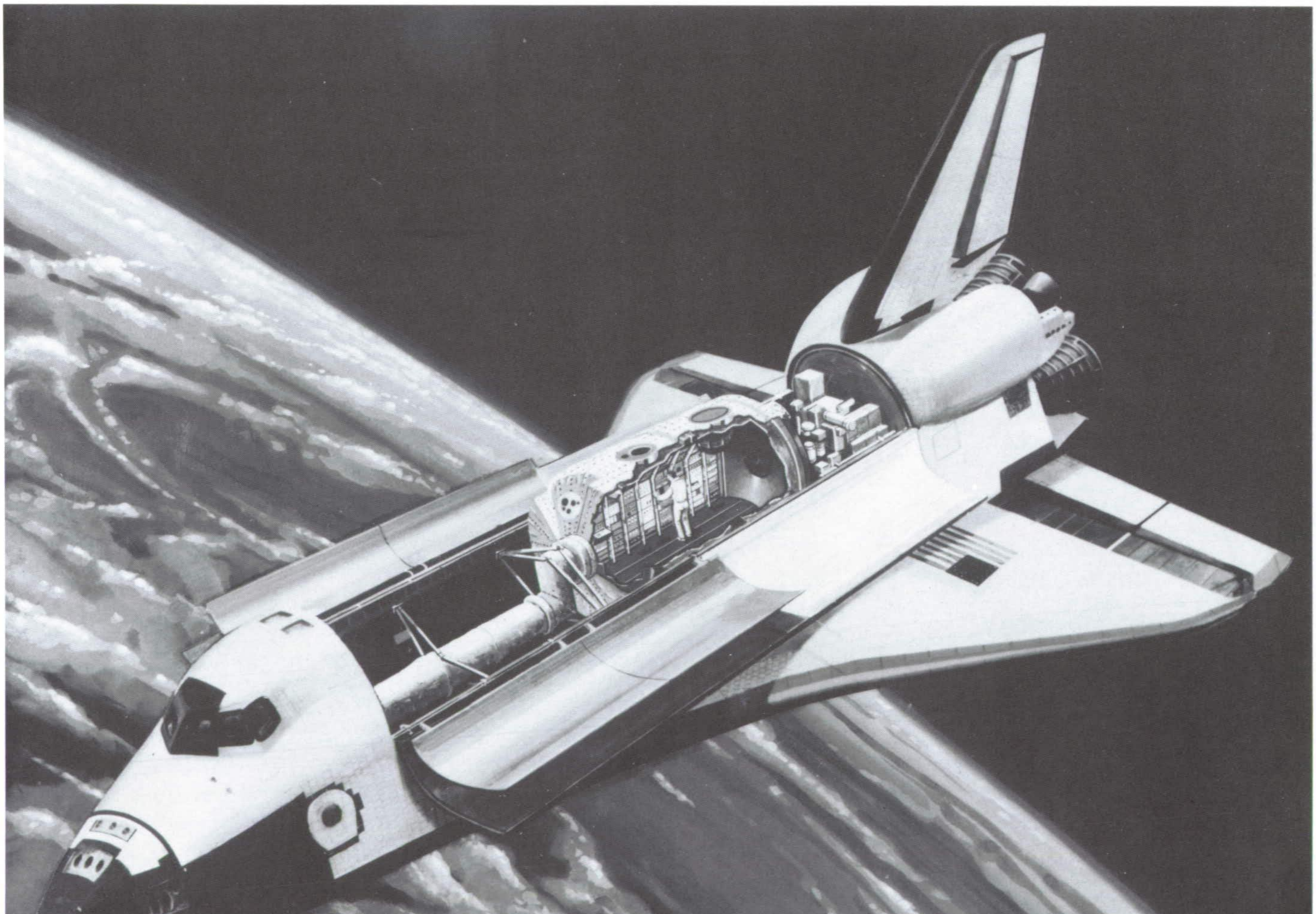
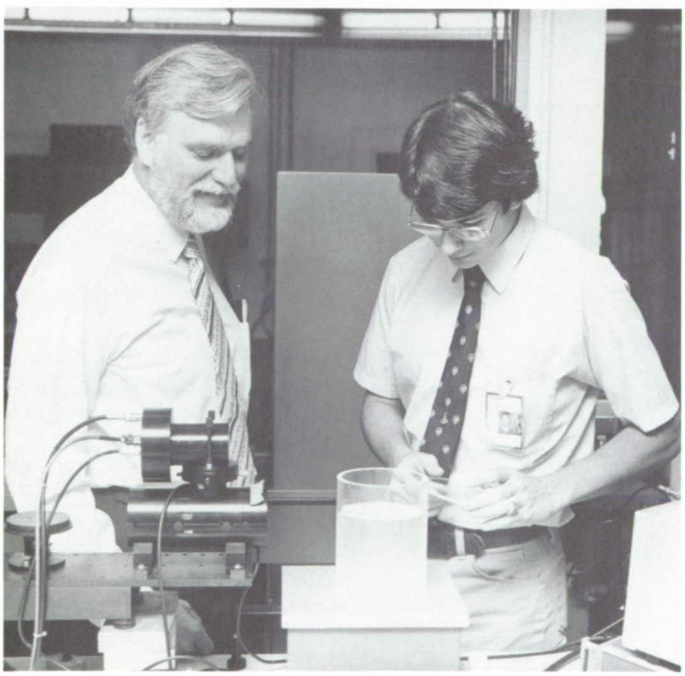


Spacelab and other payload carriers convert the Orbiter into a research facility that can benefit a broad range of science and technology disciplines.

1

Introduction



Both skilled scientists and students have designed experiments for Shuttle flights

THE CAPABILITY of the Space Transportation System (STS), the Space Shuttle, to support crew-tended and free-flyer research in low-Earth orbit has opened new possibilities for science in space. For the first time, research equipment can be put into orbit routinely, operated in either a shirtsleeve environment or exposed to space, and then returned to the investigator. The National Aeronautics and Space Administration (NASA), operator of the Shuttle, has implemented a variety of programs to ensure that anyone with a worthy research idea can take advantage of this opportunity. Investigators ranging from high school students to renowned space scientists have already used the Shuttle as a platform for making Earth, atmospheric, and astronomical observations; for performing space plasma physics measurements; and for exploring the effects of microgravity on living organisms and physical processes. For investigators considering a flight experiment for the first time, this guide explains what the Shuttle has to offer, how to arrange to fly an experiment, and what to expect once preparations for the flight are under way.

►How can I use the Shuttle for research and development?

The research uses ultimately found for the Shuttle will be limited only by the ideas of investigators. Some experiments, such as studies of spider web and snowflake formation, are intended to satisfy our curiosity about the role of gravity in everyday phenomena. Other experiments have significant practical implications and may lead to medical breakthroughs,

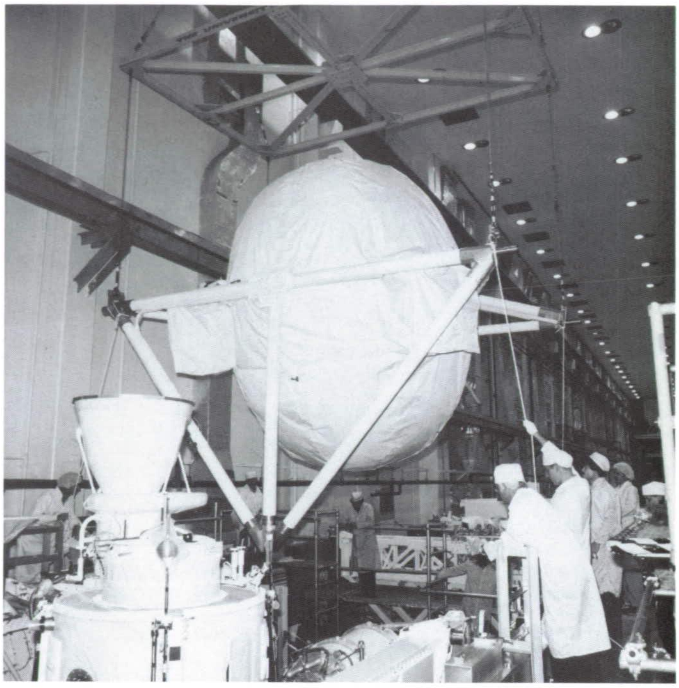
The Spacelab module allows the crew to perform research activities in a shirtsleeve environment.

new electronic materials, or improvements in Earth-based processing.

Most experiments use the Shuttle in one of three ways: as a microgravity laboratory for life sciences and materials science; as a platform for Earth, atmospheric, and astronomical observations; and to demonstrate or test new technologies. Microgravity research covering the fluid, material, and biological science disciplines is one early beneficiary of the Shuttle. Crewmembers participate in experiment setup, monitoring and adjustment, sample changeout, and data recording — conducting experiments much as they would in a laboratory on the ground. For the Earth and environmental science disciplines as well as astronomy, the Shuttle offers a vantage point above the atmosphere. Even more, it offers an economical opportunity to test new observation techniques and technologies before they are committed to more expensive satellites.

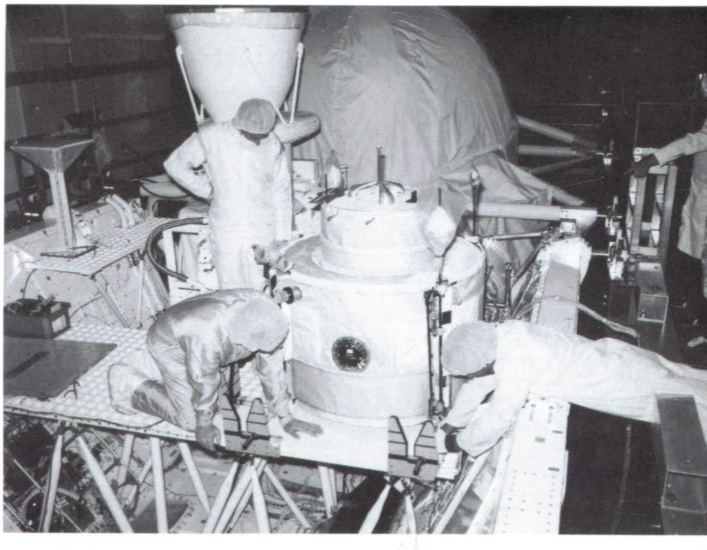
▶How are experiments accommodated on the Shuttle?

By now, the image of the Shuttle Orbiter coasting through space with its payload bay doors wide open is familiar to most everyone. The Orbiter is designed to transport large payload cargos. Spacelab and other carrier systems convert the payload bay into a laboratory for conducting science, technology, and applications investigations. These carriers are standard sets of equipment that serve as a host facility for user instruments. They include one or more mounting structures, such as the Spacelab module and pallets. They also include subsystem interface equipment to tailor the significant power, communications, and heat-rejection resources of the Orbiter to meet the needs of the individual user. Some carriers even improve on the basic capabilities of the Orbiter by providing fine pointing or specialized control, data processing, and data storage services.



The Shuttle accommodates some of the largest instruments ever flown in space.

Prior to flight, the science hardware and carrier equipment are assembled into an integrated cargo element called a payload. Although a payload may take many months to plan, assemble, and check out, it may be installed in the Orbiter, flown, and removed in the course of several weeks, thereby freeing the Shuttle for its next cargo. In this manner, the Shuttle efficiently serves the needs of those users requiring economical transportation for satellite delivery or retrieval, and it provides the science community with exciting opportunities for unconventional research.



Flight hardware and carrier equipment are put together to form an integrated payload.

▶How can I participate?

You can participate in Shuttle science missions in a number of ways. You can provide your own experiment equipment; however, it must meet specific safety and design requirements to receive flight certification. You may also use equipment developed by others. NASA has a growing inventory of multi-use equipment, primarily for materials processing and life sciences experiments, and encourages interested scientists to take advantage of it. In this case, you may simply define how you need to use the equipment to accomplish your objectives and, if necessary, provide samples for processing.

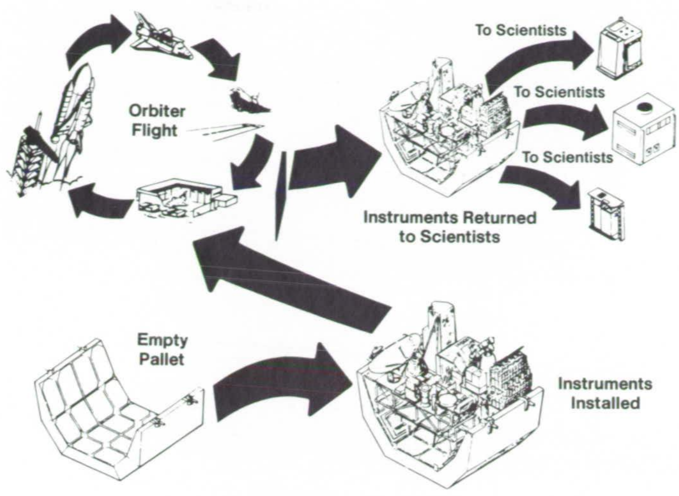
▶How do I get started?

Finish reading this guide. Study the capabilities and accommodations of the Orbiter and its payload carriers and determine how they can be used to meet your science objectives. Understand your responsibilities should you be accepted into a payload program. Preparations may take several months to several years, depending on the program; it is important that you be aware of your role in the end-to-end process prior to committing to a flight. If you need funding, contact NASA Headquarters about research opportunities. If you will be developing your own experiment equipment, plenty of helpful guidance is available from NASA engineers and from a growing list of experienced contractors; more extensive assistance can be arranged.

Don't hesitate. The future of space research is bright. The Shuttle is operational again, and Space Station Freedom will be in orbit soon. The place to get started is here; the time to get started is now. ■

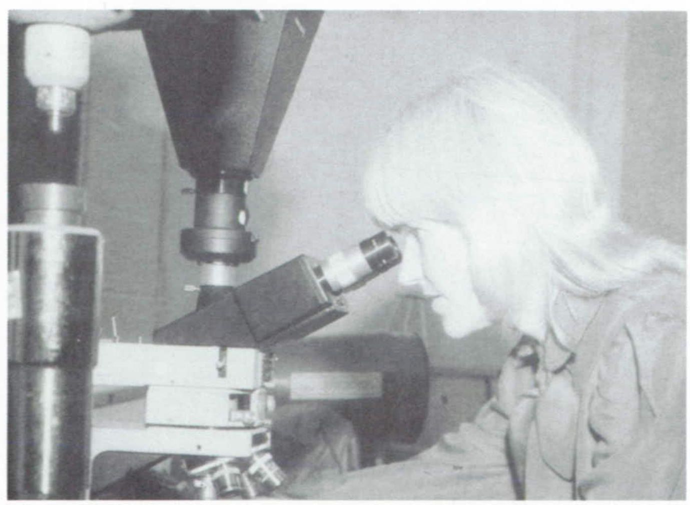
Speaking the Language

Space is not a foreign country, but to the initiate the language makes it seem that way. NASA has developed a specialized terminology to describe the roles that people and equipment play. As an investigator or experimenter, you are either a Principal Investigator (PI) or Co-Investigator (Co-I), depending on your responsibilities. The flight equipment (hardware and software) used to conduct an experiment or make an observation is called an Experiment Payload Element (EPE). On the ground one would use the term experiment apparatus or instrument. An Experiment Payload Element Developer (EPED) or, more generally, a Payload Element Developer (PED) develops experiment flight equipment. A mission is the performance of a coordinated set of operations in space to achieve specific program goals. These operations involve the Shuttle, its crew, and its payloads. More than one mission may be accomplished on a single flight, and from a technical standpoint, more than one flight may be required to accomplish a single mission. However, the terms "mission" and "flight" are often used interchangeably. You will become familiar with other terms and acronyms as you read this document. A list of all acronyms can be found on page 75.



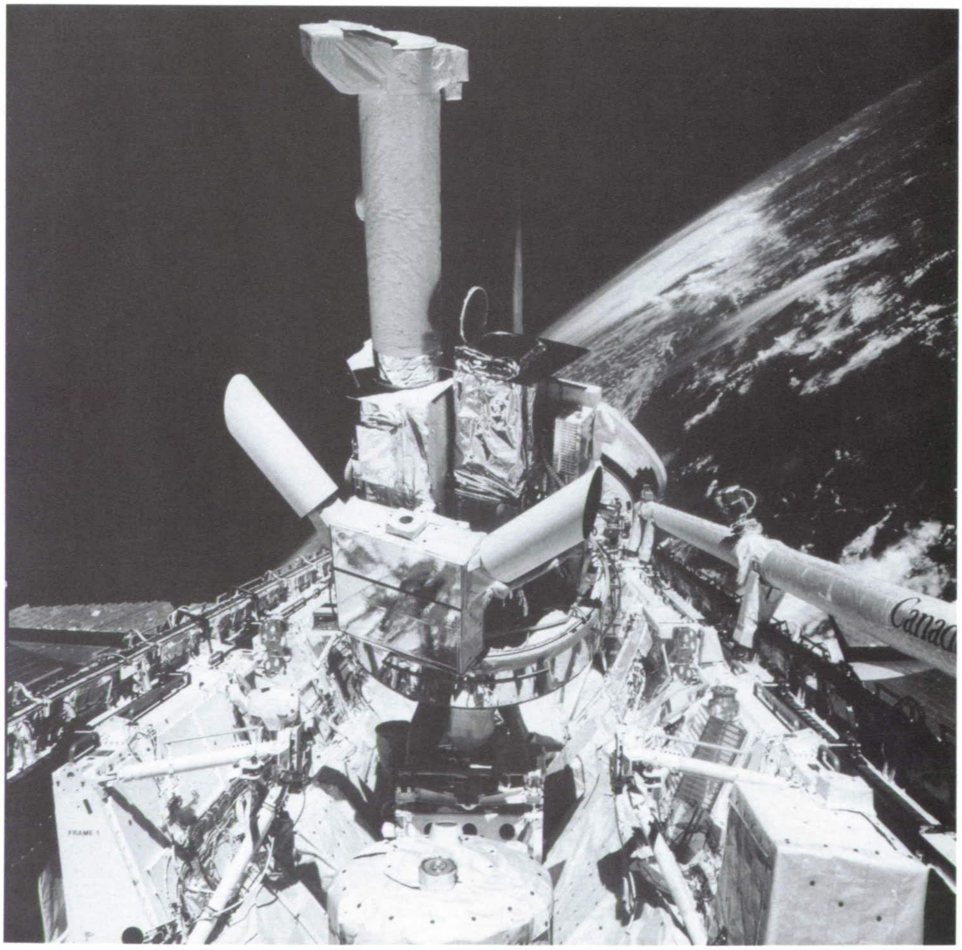
Shuttle Science Payload Concept

Scientists monitor flight data and sometimes control their experiments from the ground.



Similar skills are used in ground-based and space research.

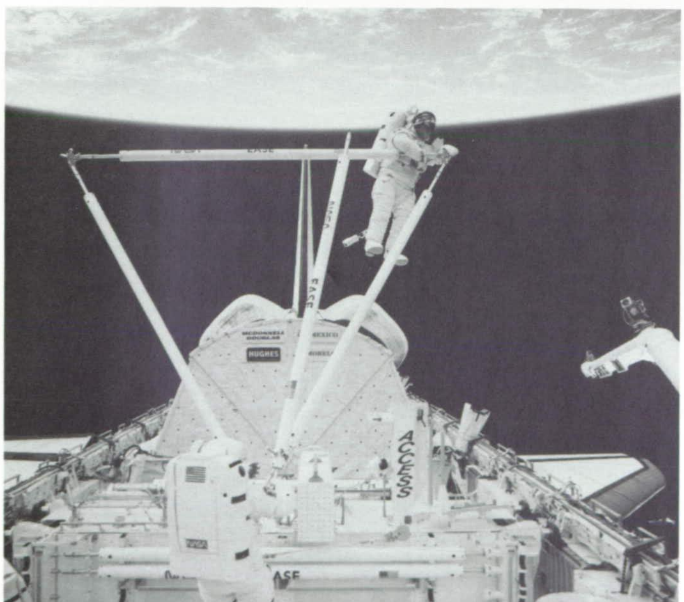
Notes:



The Shuttle offers a vantage point for Earth, atmospheric and astronomical observations. Here the Instrument Pointing System aims a cluster of telescopes during the Spacelab 2 mission.

2

Getting On Board



The Office of Aeronautics and Space Technology (OAST) sponsored investigators from the Massachusetts Institute of Technology and the Langley Research Center who studied how astronauts might build structures in space.

FOR A TYPICAL INVESTIGATOR, one of the first steps in getting on board is to seek sponsorship and funding for the experiment project. Investigations that use the STS come from many sources. NASA maintains active research and technology development programs and sponsors a large number of flight experiments. Commercial enterprises, universities, other U.S. agencies, and agencies of foreign governments are additional sources of flight experiments. To encourage the development of space for commercial purposes, NASA has established several types of joint arrangements that defer some costs of product development until commercial potential has been established. These are in addition to normal reimbursement arrangements. These sponsorship and working arrangements provide good opportunities for investigators with worthy ideas to participate in space research on the Shuttle.

An investigator's early contact with the agency before mission assignment usually occurs through NASA Headquarters in Washington, D.C. Investigators seeking sponsorship usually work with either the Office of Space Science and Applications (OSSA) or the Office of Aeronautics and Space Technology (OAST). Science investigations in such traditional discipline areas as life sciences, astrophysics, solar system exploration, Earth observation, space physics, and microgravity sciences fall under OSSA. Technology development for new space systems is the responsibility of OAST. Payloads and investigations that are purely commercial in nature, or that are sponsored by commercial organizations, are under the cognizance of the Office of Commercial Programs, which in turn works with the other appropriate program offices at NASA Headquarters. Cooperative international missions are arranged

European scientist-astronaut, Dr. Ulf Merbold, inserts a sample in the Materials Science Double Rack on the Spacelab 1 mission. Materials Science is one of several research areas sponsored by the Office of Space Science and Applications (OSSA).

OSSA and OAST sponsor most NASA space research and technology projects:

Office of Space Science and Applications (OSSA)

- *Astrophysics*
- *Communications*
- *Earth and Planetary Exploration*
- *Earth Observation*
- *Life Sciences*
- *Microgravity Science and Applications*
- *Space Physics*

Office of Aeronautics and Space Technology (OAST)

- *Automation and Robotics*
- *Humans in Space*
- *In-Space Systems*
- *Sensors and Information Systems*
- *Space Structures*
- *Fluid Management and Propulsion Systems*
- *Power Systems and*
- *Thermal Management*
- *Space Environmental Effects*

NASA Headquarters, Washington, D.C. 20546

- *International Affairs Office*
  Code XI
  202-453-8440
- *OSSA Discipline Offices*
  Code E
  202-453-1430
- *OAST Technology Offices*
  Code RS
  202-453-2733
- *Office of Commercial Programs*
  Code CC
  202-453-1890
- *Transportation Services Division*
  Code MC
  202-453-2347

through a NASA Program Office and the International Affairs Office. Those investigators planning to fly experiments on a reimbursable basis work with the NASA Office of Space Flight.

►Seeking NASA Sponsorship

NASA-sponsored investigations are selected from proposals submitted under any of several circumstances:

- Solicited
- Unsolicited
- Per agreement
- Per a NASA critical need.

Announcements of Opportunity (AOs) solicit proposals for investigations responsive to specified broad program objectives or within specific disciplines. This announcement states the range of subjects appropriate for proposals, the proposal format required, where to send proposals, the deadlines involved, and the selection schedule. Some AOs are open-ended, with periodic review of proposals.

Unsolicited proposals include any proposal not prepared as a direct result of a formal NASA solicitation. From time to time, NASA issues notices that describe ongoing programs and areas of activity appropriate for unsolicited proposal submission. These often take the form of Dear Colleague letters. Unsolicited proposals need not be submitted in a particular format; however, all proposals must contain sufficient scientific, technical, and budgetary information to allow a thorough and equitable review. NASA is under no obligation to respond to unsolicited proposals and may consider them only as correspondence.

All solicited and unsolicited proposals are reviewed for scientific and technical merit by a panel of peers. Proposals are reviewed further to assess the type of accommodation mode that the investigation requires (Spacelab module, pallet, Orbiter middeck, etc.), the feasibility of developing the flight equipment needed and of providing the flight resources required, and the efficacy of the management approach outlined (including schedule and costs). The provisions of NASA Handbook NHB 8030.6A, "Guidelines for Acquisition of Investigations," control the evaluation and selection process. Following additional internal reviews, the Associate Administrator of the sponsoring office selects investigations for definition studies, taking into account the review recommendations as well as NASA's programmatic needs and priorities. Selection usually occurs 6 months to 1 year after proposal submission.

Tentatively selected investigations, depending on development status, undergo a thorough science and implementation requirements definition study so that a complete and realistic development plan for the investigation can be produced. This plan covers all phases of the project from development of the equipment, through operation of the equipment on orbit, to the postflight data analysis and production of papers suitable for publication.

Occasionally, NASA formally agrees to support and participate in cooperative space research with other U.S. agencies and with agencies representing foreign governments. In these cases, the selection process is controlled by a joint agreement.

Contact OSSA or OAST to find out about current opportunities.

►Joint Agreements for Commercial Users

NASA actively supports the expansion of U.S. private sector investment in civil space activities and encourages the development of new markets for Shuttle services. To that end, NASA has pioneered several classes of joint working

agreements with industry to provide incentives for early commercialization efforts while at the same time protecting the proprietary interests of participating companies. These agreements are negotiated on a case-by-case basis and can be tailored to the specific needs of a given project. The terms typically cover factors such as rights to data and patents, process exclusivity, and circumstances for recoupment of NASA's investment.

For companies interested in the application of space technology but not ready to commit to a specific space flight experiment or venture, a Technical Exchange Agreement (TEA) has been developed. Under this type of agreement, NASA and the participating company agree to exchange technical information and to cooperate in ongoing ground-based research and analyses. In this way, a firm can become familiar with space technology and its applicability to company needs at minimal expense. Under a TEA, the private company funds its own participation and derives direct access to NASA facilities such as research aircraft and drop towers and to NASA research results. NASA in turn gains the support and expertise of the industrial research capability.

An Industrial Guest Investigator (IGI) Agreement is applicable to situations in which NASA and an industrial firm share a strong mutual interest in a Shuttle flight experiment. The company appoints a scientist to participate as a member of the investigation team, again at company expense, in a NASA-directed project. This might, for example, enable the company to process samples of its choice in an existing facility.

A Joint Endeavor Agreement (JEA) is applicable for flight experiments sponsored and directed by companies. By offering Shuttle flight time and technical advice, NASA reduces the cost and risk of product development until the viability of key technologies is established. While the terms of each JEA are negotiable, a company must typically commit sufficient funding to carry the project through the phases of feasibility studies and planning, flight experimentation and technology development, and applications demonstrations. NASA usually has either a scientific or technical interest in a JEA with some rights to data or information.

Contact the Office of Commercial Programs (OCP) at NASA Headquarters for additional details.

NASA offers several types of joint working agreements to encourage private sector space research:

Agreement	*Company Benefit*
Technical Exchange Agreement (TEA)	• *Use of NASA ground and aircraft facilities* • *Access to NASA research results*
Industrial Guest Investigator (IGI)	• *Participation in ongoing NASA space research*
Joint Endeavor Agreement (JEA)	• *Deferral of Shuttle flight cost* • *Process exclusivity* • *Data and patent rights*

Under a Joint Endeavor Agreement with NASA, McDonnell Douglas has flown the Continuous Flow Electrophoresis Experiment five times. Investigators want to see if purer pharmaceutical products can be produced in space.

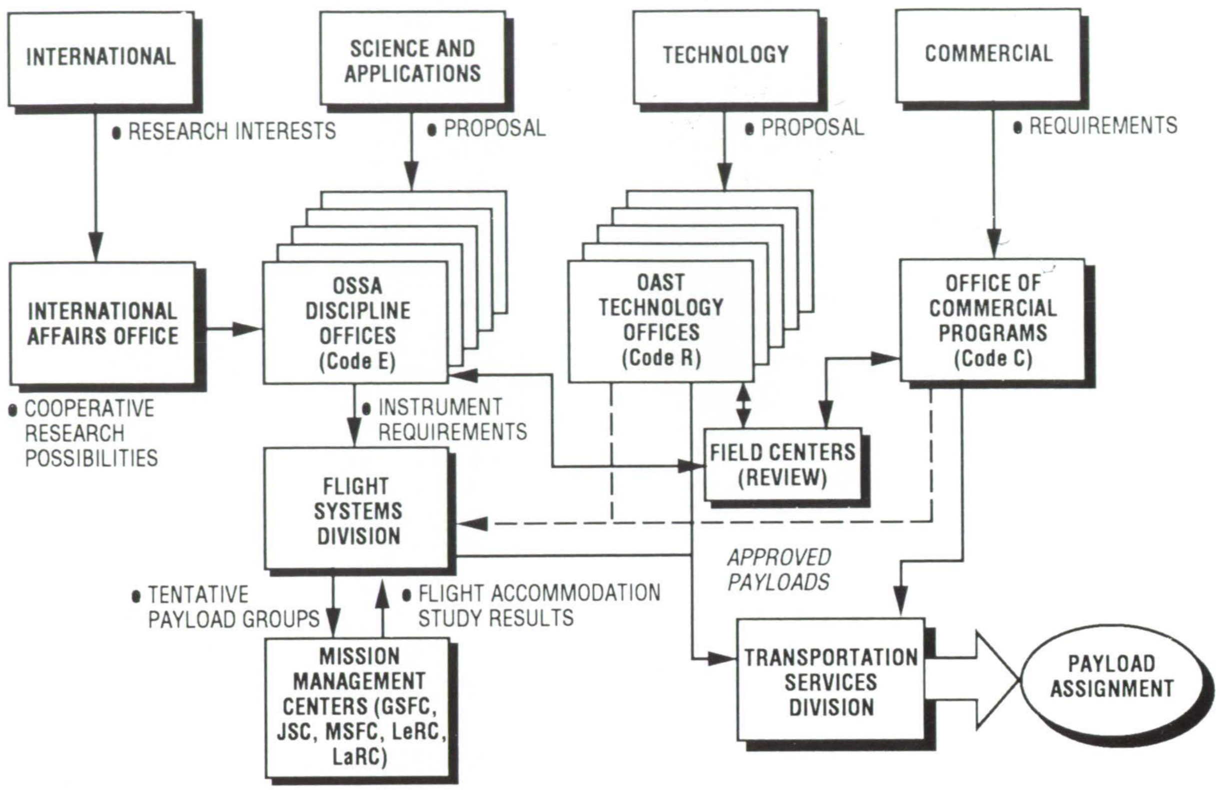
▶Reimbursement for STS Launch and Related Services

Investigators sponsored by NASA are not required to provide reimbursement for STS launch costs since these costs will have been accounted for by the NASA sponsoring organization. Also, as previously discussed, STS launch costs can be deferred for potential commercial users through Joint Endeavor Agreements.

Investigators wishing to secure STS launch services on a basis other than as described above should consult NASA documents entitled STS Reimbursement Guide (JSC-11802) and NSTS (National Space Transportation System) Optional Services Pricing Manual (JSC 20109). These documents are a source of information for financial planning and for estimating the price of an STS launch and related services. Contact the Transportation Services Division (Mail Code MC) at NASA Headquarters for additional information on STS pricing policy.

▶Mission Assignment

Science instruments are assigned to payloads by the Flight Systems Division of OSSA. For instruments with modest resource demands and no special accommodation require-



The NASA organization offers specialized points of contact to better meet the needs of each user class.

ments, this may be a simple matter of adding the instrument to an on-going mission or queue. For large Spacelab missions, the Flight Systems Division works with the NASA field centers in an evolving process to establish the makeup of the payload group and to develop a mission payload concept. Preliminary mission studies based on descriptive data from proposals and other sources are conducted to determine technical feasibility and to develop cost data. The results are evaluated with regard to NASA's other program priorities, and a decision is reached on mission funding and schedule.

Payloads approved by OAST and OCP have several alternate paths that can be taken for implementation. They can go to the Flight Systems Division; they can go to some center organization; or in the case of OCP, they also could go to some commercial organization such as Spacehab, a commercially developed laboratory module that is scheduled to be available in 1991.

The Shuttle with its payload systems can support the operation of a large group of instruments on each flight; therefore, compatibility is an important consideration in establishing mission payload groups. The combination of instruments must be physically and operationally compatible with the STS and the selected payload carrier. In general, for a given flight or series of flights, the tentatively selected experiments are grouped by discipline to provide maximum scientific data return from the various research areas, minimum interference among experiments, and maximum feasible use of common facilities, sensors, and data processing equipment.

The first major milestone in the life cycle of a mission is approval for flight. At this point, a commitment is made in the NASA budget, a tentative launch date is selected, mission responsibility is assigned to one of the NASA field centers, and a Payload Mission Manager (PMM) is appointed to coordinate mission development. The mission manager is responsible for defining the mission and the additional equipment needed to combine the instruments into an integrated payload ready for flight.

►What an Investigator Needs to Know About the NASA Organization

Within NASA, project management responsibilities for experiment hardware and science payloads reside with the various field centers around the country. Those investigators whose experiments are selected for NASA sponsorship interface with a discipline or experiment project office for hardware development and funding. The project office monitors the development status of the experiment equipment and provides technical assistance to ensure that the end product meets its design and performance requirements.

The investigator's primary interface for payload integration is with a payload project office. Within this office a mission manager or project manager serves as the investigator's principal point of contact. This mission or project manager has full responsibility for directing integrated payload development and mission implementation. In this regard, the PMM consolidates and coordinates the requirements for all investi-

gations on the mission and then works with the managers of the STS operation and support elements to satisfy those requirements in such areas as crew selection and training, ground and flight operations planning, control center requirements, and data processing requirements.

Specific operational and support responsibilities for the Shuttle and its science payloads are assigned to several of the NASA field centers. Preparatory and operational phases of the mission normally require the investigator to participate in activities at one or more of these centers.

The Johnson Space Center (JSC) near Houston, Texas, is responsible for all Shuttle flight operations activities. These include real-time flight operations, the analytical aspects of cargo integration, Orbiter flight planning, and crew training. Orbiter flight operations are managed through the Mission Control Center (MCC) at JSC.

Payload real-time flight operations are coordinated through Payload Operations Control Centers (POCCs) where working accommodations are provided for investigators. The NASA POCC for Spacelab missions is located at the Marshall Space Flight Center (MSFC) in Huntsville, Alabama. Other payload missions are supported by POCC capabilities at JSC, the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, and the German Space Operations Center (GSOC) near Munich, West Germany.

In most cases, payload integration and checkout require the investigator's presence at the Kennedy Space Center (KSC) in Cape Canaveral, Florida. KSC plans and manages the ground processing of cargos for integration into the Orbiter. This activity typically includes the physical integration of user science instruments onto the carrier, checkout of the integrated payload, and loading of payloads into the Shuttle. However, some payloads are integrated and checked out before being transported to KSC.

GSFC performs data capture and postflight data processing for Spacelab missions. Goddard also manages the Tracking and Data Relay Satellite System (TDRSS) and the NASA Communications Network (NASCOM), which provide voice and data communications links between the Spacelab Data Processing Facility and the rest of the Spacelab data network.

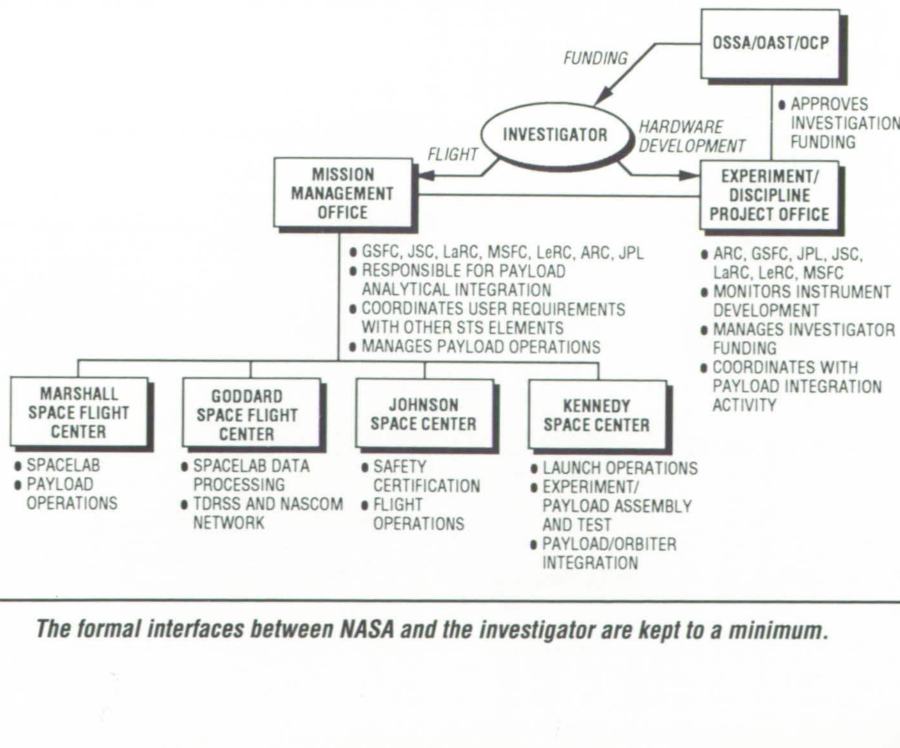
The mission manager arranges for the investigator to use facilities at these centers, as required.

▸Coordinating Mission Science

An Investigator Working Group (IWG) is formed for Spacelab and other major missions to assist the mission management team in obtaining maximum science return within allocated mission resources. It is composed primarily of the Principal Investigators (PIs) or their representatives. The IWG is chaired by a NASA mission scientist appointed by the center director of the NASA field center with mission management responsibility. The mission scientist orchestrates and structures the needs of the science teams and serves as the primary interface between the mission manager and the investigators.

The IWG facilitates communications among the various investigators and provides a forum for the discussion of issues affecting the accomplishment of experiment objectives. Shuttle attitude, mission timeline, and crew involvement are typical discussion topics. The IWG provides scientific and technological guidance to the mission manager in the development of a sound mission plan and remains active until mission completion. The IWG determines the need for payload specialists and develops selection criteria to choose these crewmembers, scientists/astronauts who perform experiments in space. ■

The Investigator Working Group plays a key role in coordinating mission science requirements.



The formal interfaces between NASA and the investigator are kept to a minimum.

Notes:

3
The Orbiter

YOUR EXPERIMENT depends on the Space Shuttle Orbiter for critical services and resources such as power, communications, pointing, and active thermal control. In most cases, Orbiter services and resources are distributed and augmented by a payload carrier, but a number of basic user requirements can be satisfied directly by the Orbiter. By studying the Orbiter systems and inherent capabilities, you can better understand how the Orbiter and the various payload carriers can work together to meet your operational objectives.

▸Where It Goes

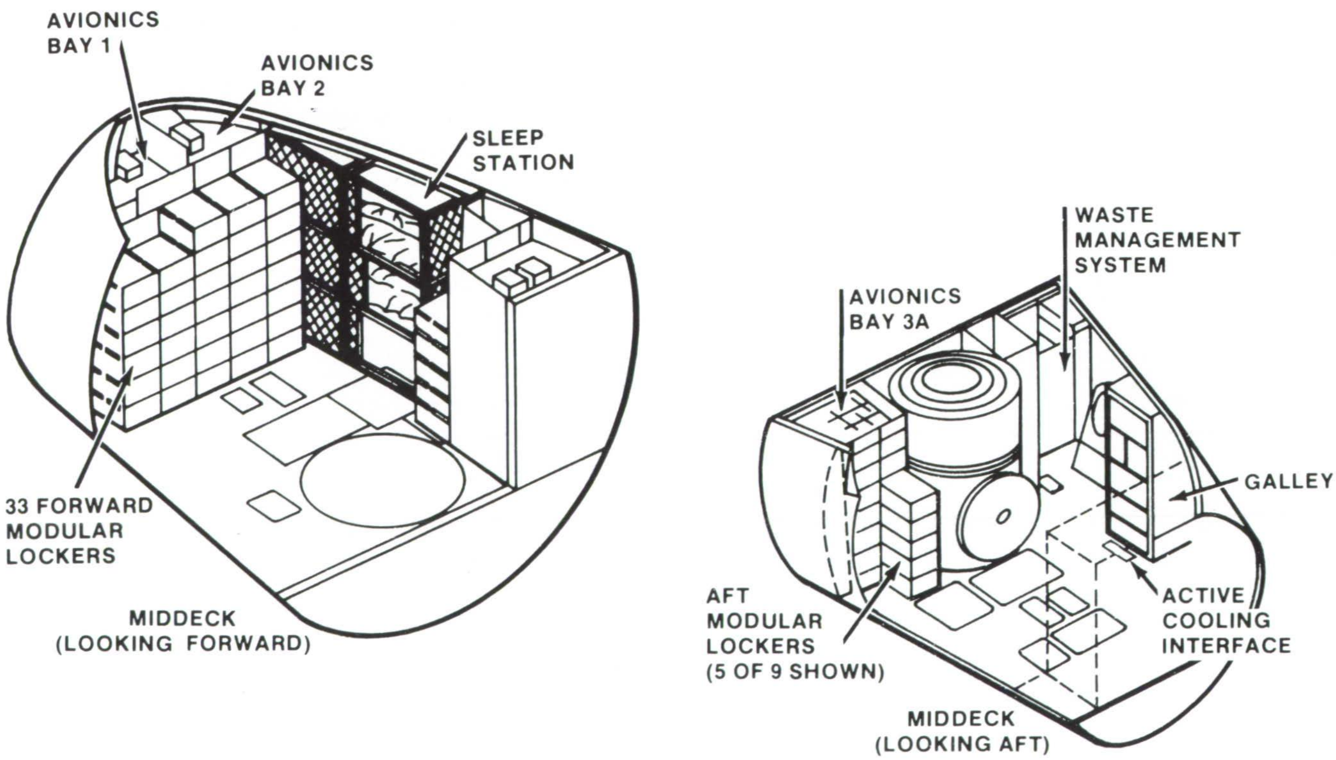
From Kennedy Space Center in Florida, the Orbiter can achieve altitudes from 135 to 300 n. mi. (250 to 556 km) and any orbital inclination from 28.5 deg to 57 deg. The nominal altitude for most flights is 160 n. mi. (296 km). For flights dedicated to a single science mission, specific orbital parameters are selected that best meet the collective needs of the investigators. These missions typically fly in either a 28.5-deg orbit or a 57-deg orbit. Shared or mixed cargo flights more commonly enter a 28.5-deg orbit; orbit parameters are determined by the primary payloads. The nominal flight duration for science missions is 7 to 10 days. However, a flight extension kit is currently being developed to sustain missions as long as 16 days. This capability will be available in 1992.

▸The Floor Plan

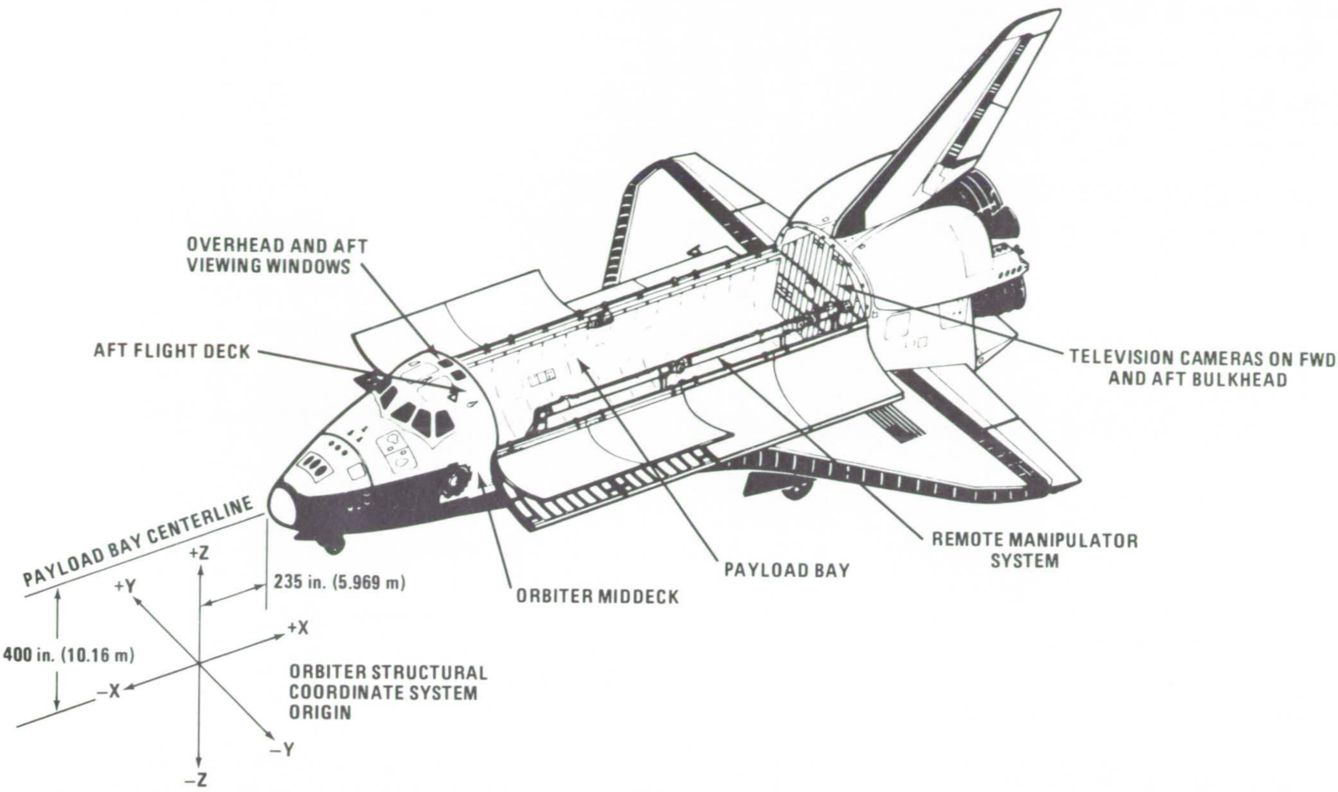
The payload bay, aft flight deck, and middeck are areas of the Orbiter that help accommodate investigator requirements. The payload bay occupies the midsection between the flight deck and crew quarters in the front of the Orbiter and the engine

User accommodation needs are met by a combination of inherent Orbiter capabilities and carrier provisions:

User Needs	Carrier Accommodations	Orbiter Capabilities
Specific Orbit Parameters		Orbit Altitude/Inclination
Crew Service	Pressurized Work Space	Payload Crew
Instrument Pointing	Fine Pointing System	Coarse Pointing
Instrument Mounting	Attachment Interfaces Equipment Racks Hardpoints Bolt Patterns	Payload Bay Trunnion Attach Fittings Sidewall Mounting Middeck Payload Mounting
Subsystem Interfaces Electrical Power Heat Rejection Command and Data Science Data Handling/Downlinking Onboard/Ground Monitoring Onboard/Ground Commanding Onboard Data Processing Video	Interface Equipment Distribution and Breaker Protection Thermal Control Interfaces Cold Plates Fluid Loop Interfaces Avionics Air Command and Data Interfaces Data Multiplexer/Data Recorder Low Rate Data Channels Command Channels Computer/Controller Video Switching/Recording	Subsystem Buses: Electrical Power Thermal Payload Heat Exchanger Middeck Water Loop Data/Communications Ku-Band Downlink GPC/Operational Downlink GPC/Operational Uplink GPC/GNC/Time Services Video Recording/Ku-Band Downlink
Stowage	Stowage Containers	Middeck Lockers
Deployment/Retrieval		Remote Manipulator System



Layout of the Orbiter Middeck



Several areas of the Orbiter play a role in accommodating investigator requirements.

assemblies in the rear. The maximum payload envelope is cylindrical with a diameter of 15 ft (4.6 m) and a length of 60 ft (18.3 m).

Investigators who use the payload bay may encounter references to the Orbiter coordinate system. The origin is external to the Orbiter and lies ahead of the nose and 400 in. (10.16 m) below the centerline of the payload bay. The axes are identified as X_o, Y_o, and Z_o. Positive X_o is toward the tail; positive Y_o is in the direction of the right wing; and positive Z_o is up out of the payload bay. Occasional reference may also be found to the 13 "bays" defined by the fuselage frame stations. Bay numbering starts at the forward end and each bay is about 5 ft (1.5 m) long.

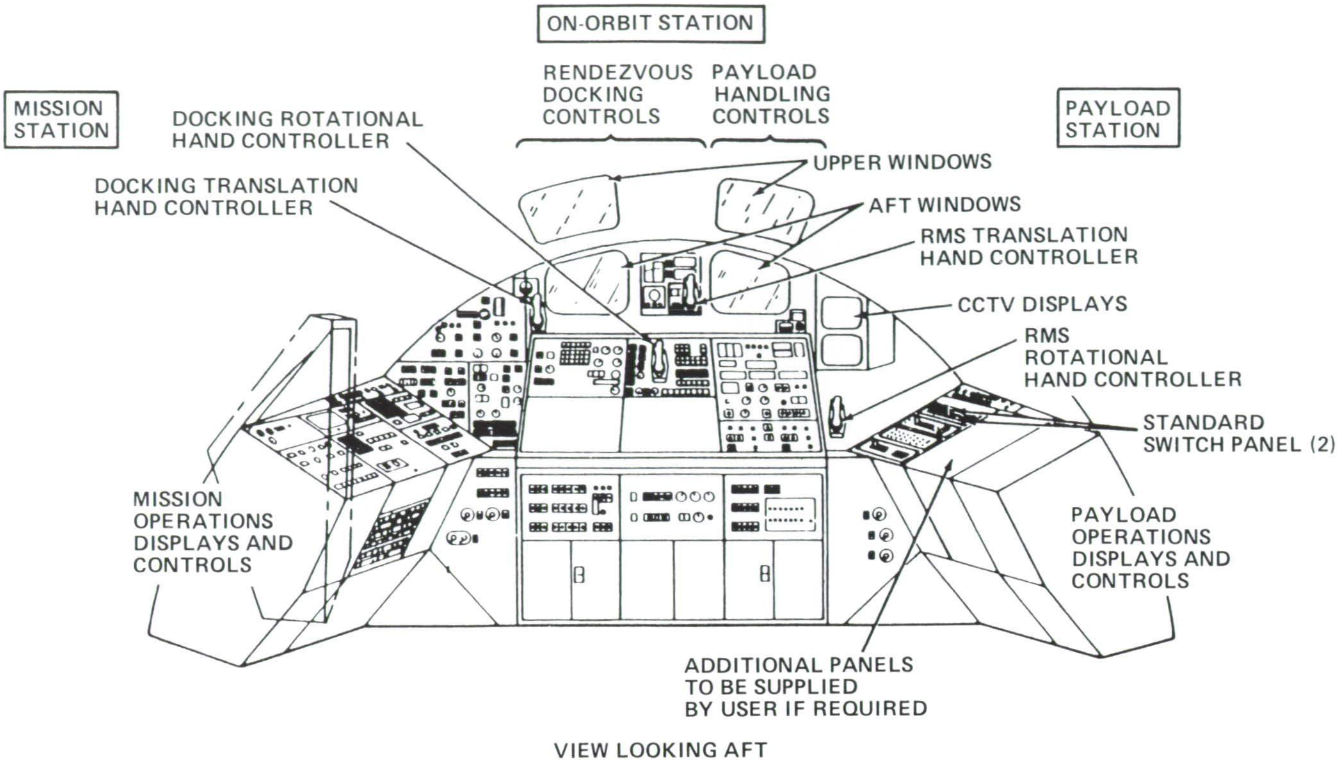
The Remote Manipulator System (RMS), a 50-ft (15-m)-long articulated arm for deploying, maneuvering, and recovering payload elements, is mounted along the left side of the bay. The arm is an optional item that is included on flights as necessary.

The aft flight deck overlooks the payload bay and contains video display equipment, a data terminal, and switch panels for controlling and monitoring cargo activities. Located under the flight deck, the Orbiter middeck contains sleeping stations, the galley, waste management provisions, and two banks of stowage lockers. These lockers normally hold food, clothing, and equipment for the crew. Unused lockers and/or their mounting spaces are made available for experiment equipment on a mission-by-mission basis. Egress to the payload bay for extravehicular activities (space walks) and to the Spacelab module also occurs through the middeck. An airlock can be installed either in the middeck or just outside in the payload bay, depending on mission requirements.

▶The Orbiter as a Platform in Space

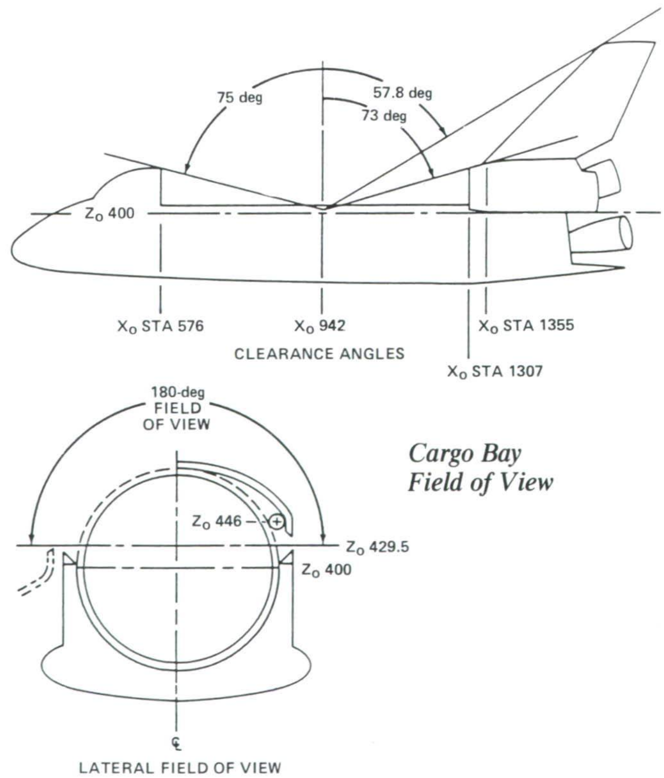
Field of view, pointing accuracy, attitude holding constraints, and the microgravity environment are all features that characterize the Orbiter as a platform on which to conduct science and technology investigations. With regard to field of view, the cargo bay doors open from 1 to 3 hours after launch, providing pallet-mounted instruments with a broad exposure to space. The view envelope is limited in the longitudinal direction by the forward and aft bulkheads, the tail, and adjacent payloads. In the lateral direction, a 180-deg field of view is available above the Z_o 429.5 in. (10.91 m) level, about 2.5 ft (0.75 m) above the payload bay centerline. Where the RMS, centered at the Z_o 446 in. (11.33 m) level, is present, payload and flight operations will be planned so that the RMS does not interfere with payload viewing objectives.

Orbiter pointing is controlled by the Inertial Measurement Unit (IMU) located in the forward end of the vehicle. The pointing reference is established by star trackers and



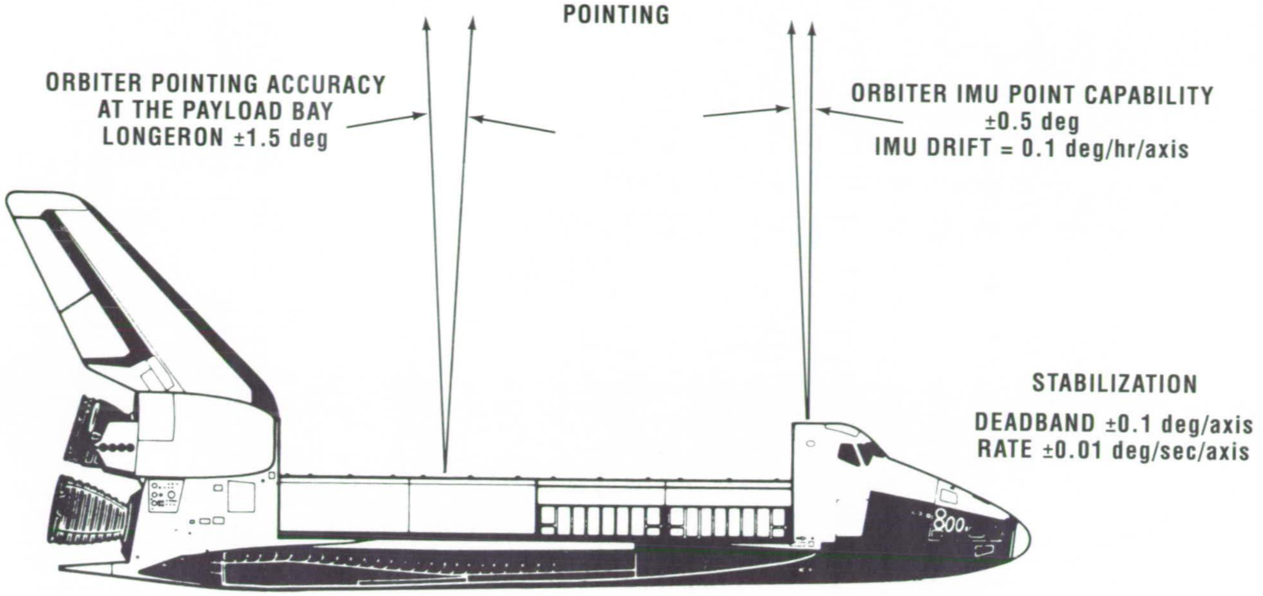
The aft flight deck serves as an onboard operations center for payloads that do not include the Spacelab module.

The overhead viewing windows enable astronauts to observe Orbiter surroundings.



Cargo Bay Field of View

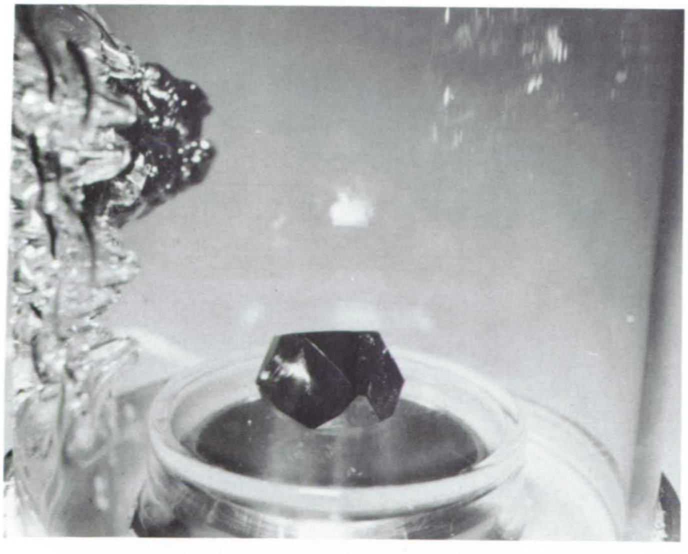
ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



Orbiter Pointing Capability

On-Orbit Acceleration Environment:

Type	*Disturbance Sources*	*Level (g's)*
Steady	Aerodynamics	$<10^{-6}$
	Gravity Gradient	$\sim 10^{-6}$
Predictable	Venting Forces	$\sim 10^{-7}$
	Vernier Thrusters	$\sim 10^{-4}$
Random	Crew Motion	10^{-4} to 10^{-3}

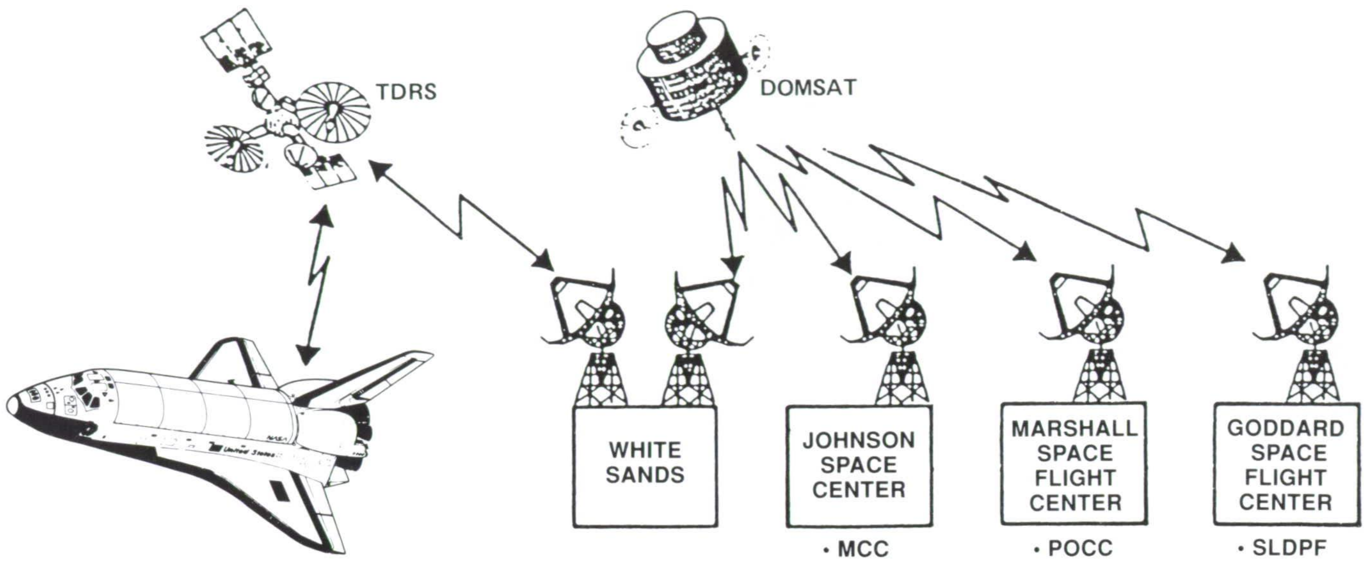


The Orbiter microgravity environment has enabled scientists to grow crystals with unusual characteristics.

maintained by gyros. A pointing accuracy of ±0.5 deg can be achieved for any desired inertial or Earth-referenced direction for periods up to 1 hour between gyro updates. Structural deformation between the navigation base where the IMU is located and the payload bay can produce an additional alignment uncertainty of up to 1 deg for payloads resulting in a total uncertainty of ±1.5 deg. However, experience to date indicates that typical inaccuracies at the payload are on the order of ±1 deg or less. The Orbiter navigation system is capable of accepting attitude information from external sensors, and alignment uncertainty can be minimized by including a pointing sensor in the integrated science payload.

The payload bay may be oriented to face Earth, the sun, deep space, or magnetic field lines as required by mission activities. Vernier thrusters adjust attitude during normal pointing operations, and the flight control system can provide a stability deadband of ±0.1 deg/axis. Excursions between these deadband limits occur at a maximum rate of ±0.01 deg/sec/axis.

Under certain circumstances, attitude holding durations may be limited by Orbiter operational and thermal design considerations. In general, these limits should not impact payload operations. An exception may occur at beta angles greater than 60 deg when the sun may shine continuously on one side of the Orbiter. In this case, vertical and anti-Earth hold durations are limited to 6 hours followed by 3 hours of thermal conditioning. Beta angle is measured between the Earth-sun line and the projection of that line onto the orbit plane.



Geostationary satellites provide a key link in the Shuttle communications network.

For many investigations, low gravity is a key attribute of the on-orbit environment. The combined aerodynamic and gravity gradient forces provide a background acceleration of around 10^{-6} g. However, crew motion and thruster firings are significant disturbance sources. While vigorous crew motion induces disturbances in the range of 10^{-3} g, periods of reduced activity can be scheduled to limit disturbances to around 10^{-4} g. Orbiter nose-up and nose-down attitudes are stabilized by gravity gradient forces and are used to minimize perturbations from thruster firings.

▶The Shuttle Data Network

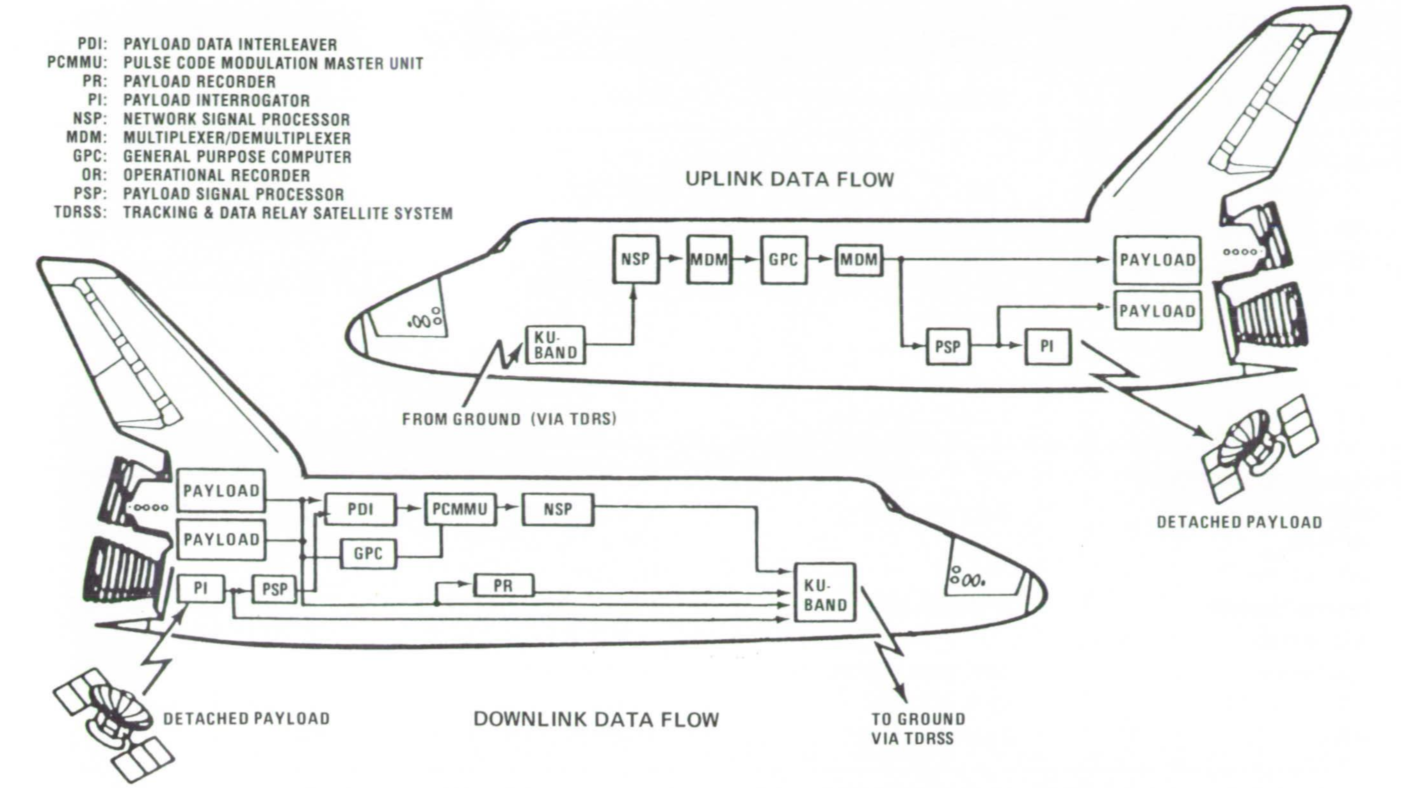
A high-capacity communications network has been established to support Orbiter and payload operations. Communications from the Orbiter to the ground occur via the Tracking and Data Relay Satellite System (TDRSS), which includes several geostationary satellites and a ground station at White Sands, New Mexico. The Domestic Satellite (DOMSAT) is used to relay data from White Sands to the major operations support facilities. Orbiter data go to the Mission Control Center (MCC) at Johnson Space Center (JSC), and payload data go to a designated Payload Operations Control Center. Payload operations may be controlled from JSC, Marshall Space Flight Center (MSFC), or Goddard Space Flight Center (GSFC). Most payload data are also sent to the Spacelab Data Processing Facility (SLDPF) at GSFC for recording and processing.

Although the Orbiter can transmit and receive over both S-band and Ku-band radio channels, the Ku-band system provides the primary communications link during normal flight operations. The Ku-band antenna, deployed from the payload bay, requires a clear view to one of the geostationary Tracking and Data Relay Satellites (TDRSs). A small gap in coverage currently exists over the Indian Ocean. Beam blockage by the Orbiter and payload structure may further affect the Ku-band link. Average nominal coverage is 85%, but coverage for individual orbits may be significantly lower.

▶Onboard Communications and Data Handling

The heart of the Orbiter Ku-band system is the Ku-band Signal Processor (KuSP). This signal processor can simultaneously transmit three input channels to the ground. Channel 1 has a total digital rate of 192 kbps and carries two voice channels, orbiter operational data and a nominal 64 kbps of payload telemetry. Channel 2 can accommodate payload data at rates of 0.016 to 2 Mbps. Depending on the operational mode of the Ku-band system, Channel 3 can handle payload digital data from several sources at rates of either 2 to 50 Mbps or 0.016 to 4 Mbps, or it can accommodate a TV or wideband analog signal from dc to 4.2 MHz. Channel 1 data are collected through a number of input paths while Channels 2 and 3 each have a single input that must be shared by all payloads.

The use of these downlink services is carrier-dependent. While compatibility studies are conducted by NASA to ensure that an instrument is assigned to the right class of carrier, a



The Ku-band network enables investigators to monitor and control instrument operations.

basic knowledge of communications accommodations can help you target your instrument to a specific carrier.

Spacelab missions offer a full complement of downlink capabilities. Science and ancillary data are transmitted through Channels 2 and 3 and a high-speed recorder is provided for temporary data storage during interruptions in the Tracking and Data Relay Satellite System (TDRSS) link. The payload telemetry provision in Channel 1 (64 kbps) is used for Spacelab housekeeping and low-rate scientific data.

Communications services are more limited on the smaller secondary payload carriers where Channel 1 is often used as the primary real-time data link. Channel 1 telemetry data are collected through the Payload Data Interleaver (PDI) and the Orbiter General Purpose Computer (GPC). The PDI can handle a composite payload telemetry rate of approximately 64 kbps and provides five input channels for attached payloads. Two other input channels are part of an S-band radio link supporting detached payload operations. The payload telemetry stream from the PDI is sent to the Pulse Code Modulation Master Unit (PCMMU), where it is combined with data from the GPC and Orbiter operational instrumentation. The master unit output is sent to the Network Signal Processor (NSP), two crew voice channels are added, and the combined voice and telemetry stream is downlinked over Channel 1 of the Ku-band system. When the satellite link is interrupted, an onboard recorder captures this data stream for later playback to prevent loss of data.

While the Ku-band downlink channels (referred to as the forward link) let users monitor their instrument status and science data streams in real time, the uplink channel (referred to as the return link) allows them to act on that information. The 216-kbps uplink data stream is demultiplexed by the Ku-band signal processor into three outputs. One output at 72 kbps contains two voice channels (32 kbps each) and an 8-kbps command channel with an effective information rate of 2 kbps. The voice channels are stripped out by the network signal processor. The command channel is sent to the Orbiter's GPC for verification and forwarding to the payload. On Spacelab-dedicated flights, the validated command stream is routed to the Spacelab experiment computer via the GPC data bus. On mixed cargo flights, this command stream is also available to attached and free-flying payloads via the Payload Signal Processor (PSP). A second KuSP output, with a rate of 128 kbps, is pipelined directly to the payload without verification. This command link is time-shared with the Orbiter text and graphics uplink capability. Most carriers are not equipped to offer this high-rate command service as a standard capability. A third output at 16 kbps is strictly overhead.

State vector and time data are also available from the Orbiter. State vector data are distributed over the general purpose computer data bus. Central "onboard time" is kept in the Master Time Unit and distributed through the Orbiter Timing Buffer in Interrange Instrumentation Group B (IRIG-B) modified code format. Both Greenwich Mean Time (GMT) and Mission Elapsed Time (MET) are available at a resolution of

Orbiter Interfaces support several classes of payloads:

Resource Area	*Dedicated (Spacelab)*	*Mixed Cargo*	*Small Payload*
Power (dc)			
Average	*7 kW*	*1.75 kW*	*1.4 kW*
Peak (15 min/3 hr)	*11.4 kW*	*3.0 kW*	
Energy			
4 Kits	*890 kWh*	*12.5 kWh/day*	*6 kWh/day*
5 Kits	*1730 kWh*		
Thermal			
Heat Exchanger	*8.5 kW continuous*	*Optional*	
Command/Data Handling			
MDM Interfaces	*Subsystems/Safety*	*Analog/Discrete*	
PDI Ports		*1 Port*	*1 Port*
GPC Data Bus		*Standard*	
Payload Recorder	*0.125 to 1 Mbps*	*3 Channels*	
Ku-Downlink			
Channel 1	*Subsystems/Safety*	*GPC/PDI*	
Channels 2/3	*Up to 50 Mbps*	*Optional*	*16 kbps–2 Mbps (shared)*
Uplink	*2 kbps/128 kbps*	*GPC/PSP*	*PSP*

10 ms. The deviation of onboard time from ground time is controlled and logged on the ground with an accuracy better than 1 ms.

The aft flight deck contains a terminal to the Orbiter computer, known as the Multifunctional CRT Display System (MCDS). With this terminal, the flight crew can interact with a payload through the general purpose computer data bus. On mixed cargo flights, a limited command and display capability is offered to each payload as a standard service. On Spacelab-dedicated flights, this terminal is used primarily for activating and monitoring Spacelab systems.

Access to the Orbiter computer data bus occurs through multiplexer/demultiplexer (MDM) units that handle data acquisition, distribution, and signal conditioning. The MDM analog and discrete interfaces are used primarily for payload activation and critical function monitoring. Several of the mixed cargo carriers provide their own payload multiplexer/demultiplexer (or bus terminal unit) for instrument interfacing. These payload systems tie directly into the Orbiter computer data bus.

A number of carriers provide their own computer-based command and data handling systems for augmented user support and limited independence from the Orbiter computer. The Spacelab system includes three computers, separate experiment and subsystem data buses, and one or more keyboard/data display units. Some smaller carriers include a microprocessor-based controller and offer a direct interface to a GRiD computer or similar display system in the aft flight deck. The benefits are greater flexibility in data handling, additional commanding options, and a capability to run specialized software to support science operations.

▶Orbiter Payload Interfaces

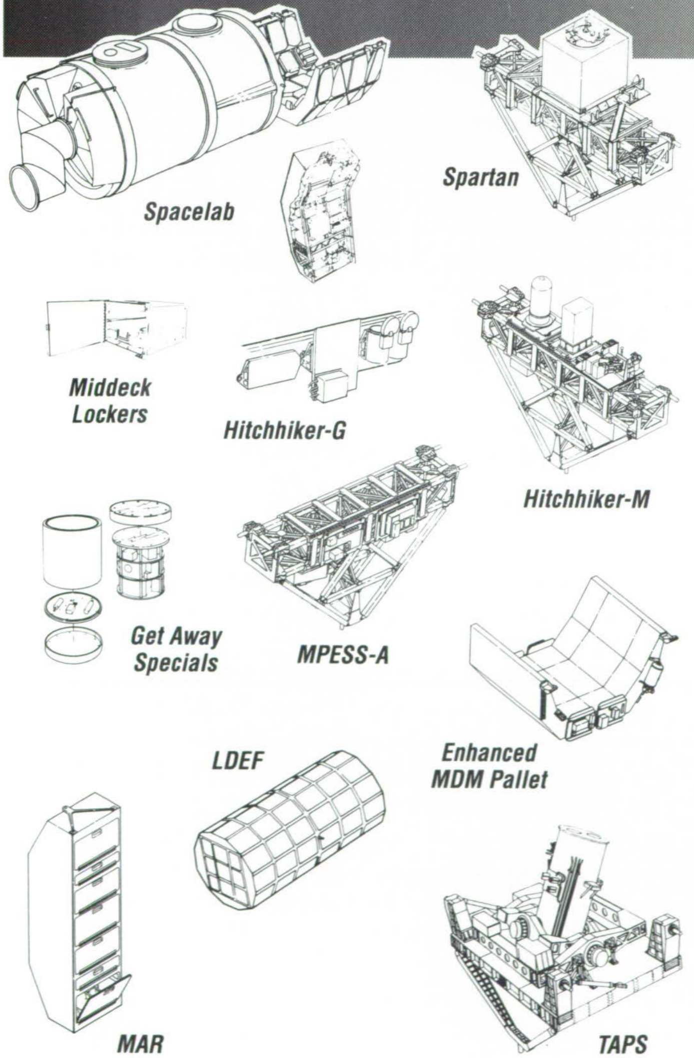
Payload accommodations have been organized to aid in equitable sharing of services among all payloads within a mission cargo manifest. Payload bay power and signal interfaces are designed to support either a single payload in a dedicated cargo mode or up to four payloads in a mixed cargo mode. In addition, a small payload accommodations mode is available through a special harness that enables small carriers like the Hitchhikers to operate without interfering with larger payloads. Spacelab is the only carrier that flies in a dedicated cargo mode and distributes the full resource capability available from the Orbiter.

In the mixed cargo mode, a basic set of electrical power and signal interfaces is routed to each quarter-bay section through a Standard Mixed Cargo Harness (SMCH), and the standard envelope of resources available to a single payload is one-fourth of the total. Some carriers use less than the standard capability; others require more. The availability of additional resources is subject to negotiation depending on the needs of the cargo partners.

Interfaces to a payload heat exchanger are available as an optional service for active liquid cooling. One channel supports a freon loop for attached payloads. Spacelab and the more capable mixed cargo carriers utilize this interface; some of the simple, quick-reaction carriers do not. A second channel supports a water loop for cabin middeck payloads. ■

4

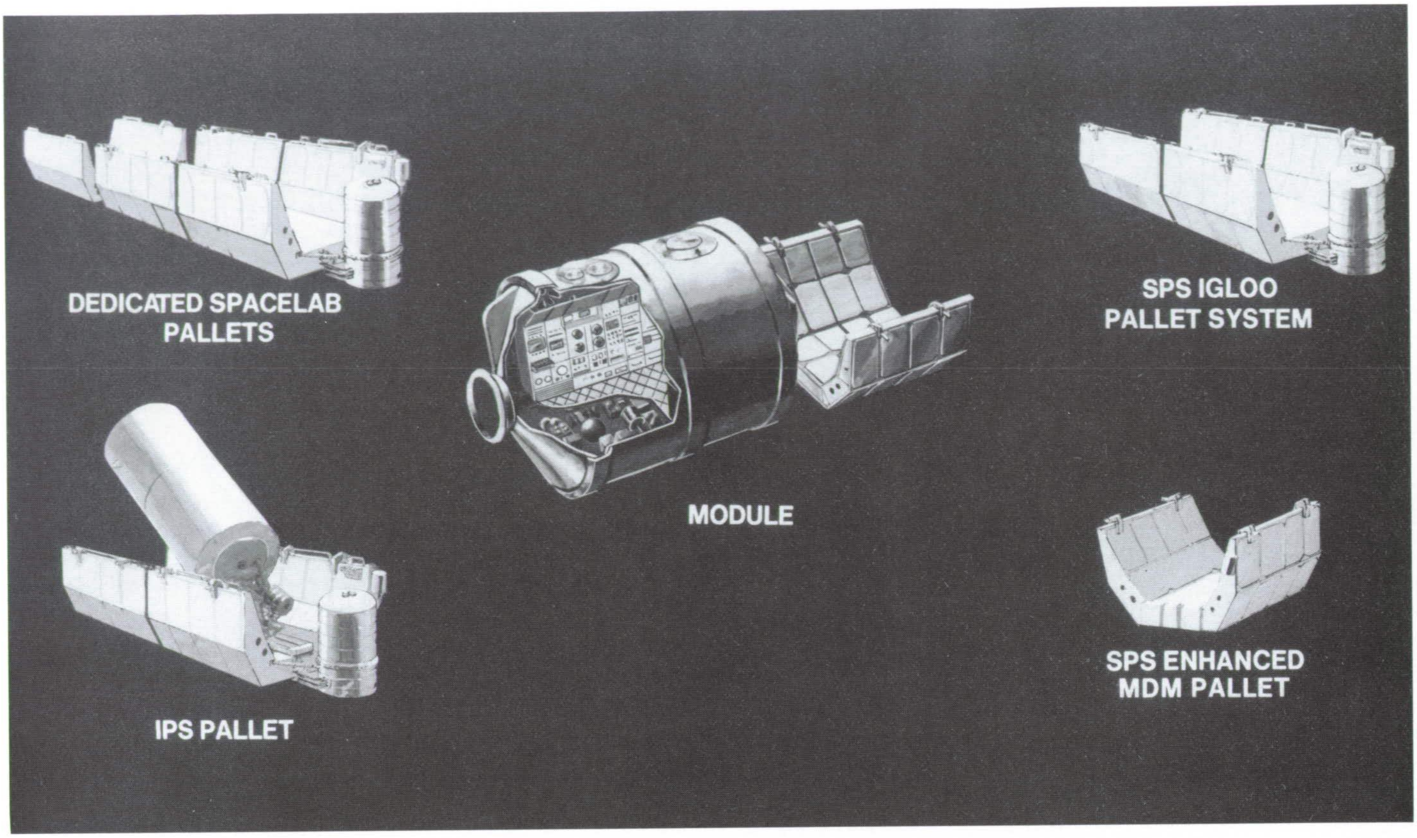
Ways to Fly



SCIENCE AND TECHNOLOGY accommodation needs vary not only from discipline to discipline but also as a research or development project evolves. To provide investigators with a broad range of options, NASA has created a variety of payload carriers. At one end of the scale is the highly flexible, full-service Spacelab, and at the other end are the economical, "no-frills" accommodations of the Get Away Special (GAS) canister.

As an investigator, you will be concerned with such factors as experiment control, data handling, electrical power, and pointing accuracy as well as other important considerations such as the number of flight opportunities each year. In this regard, significant differences exist between the available carrier systems; these differences relate to the flight mode (dedicated, mixed cargo, or small payload) and to the different types of subsystem hardware elements that make up these carrier systems. The prospective investigator should be aware that only a limited degree of commonality exists between the various carrier interfaces.

An overview of available carrier systems and their basic flight configurations is presented in this chapter. From a technical perspective, almost anything can be accomplished within the limits of Orbiter and carrier system capabilities. However, in a number of cases programmatic constraints on configuration options have been established to achieve cost and schedule benefits. If you have questions about the suitability of a particular carrier for your flight objectives, contact the appropriate project office.



A Spacelab module and pallets can be used in combinations that best meet the requirements of each mission.

►Spacelab

Spacelab was developed for the STS program by the European Space Agency (ESA). The concept of Spacelab was born from the idea of equipping the Orbiter cargo bay with a laboratory facility where the crew could operate instruments and perform experiments. The result is a highly flexible carrier system consisting of an enclosed laboratory module and open pallets that enable the user to mount equipment either in a pressurized environment or in the vacuum of space. These two major Spacelab components, the module and pallet, can be used in a variety of combinations to best meet the requirements of each mission.

Accommodations for user experiment support include a full set of control, data-handling, electrical power, and heat rejection services and specialized capabilities such as fine pointing.

The Spacelab module, which connects to the Orbiter middeck by a tunnel, is composed of two segments. The core segment contains basic Spacelab systems and the experiment segment provides additional work space. While these segments are commonly mated to form a long module, the core segment can be used alone as a short module. In either configuration, the laboratory module provides a shirtsleeve environment in which the crew can set up equipment, monitor experiment progress, and react to unforeseen developments. They do experiments just as they would in their own laboratories, using their dexterity, insight, and intuition.

Pallets are large, open platforms designed to support instruments and experiments that require direct exposure to space. Pallets can be flown individually or hooked rigidly together in trains of two or three. Up to five pallets can be flown without the laboratory module: three pallets can be flown with a short module, and two pallets can be flown with a long module.

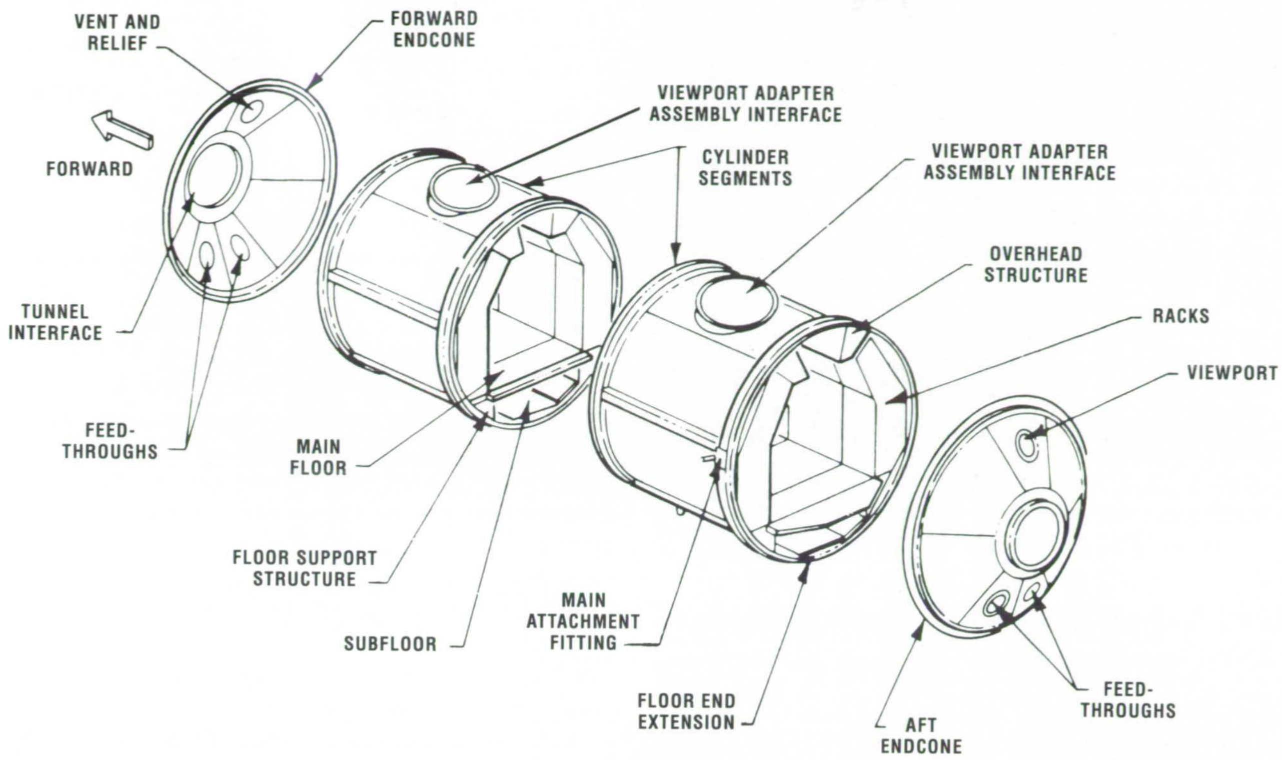
For pallet-only configurations, a large canister called the igloo houses vital data and power control system elements in a pressurized and thermally controlled environment. The igloo and a number of system elements not housed in the igloo are attached to the front frame of the first pallet.

Module Features

The core and experiment segments of the Spacelab module are cylinders 13.5 ft (4.1 m) in outside diameter and 9 ft (2.7 m) in length. When assembled with end cones, they form a structure 23 ft (7.0 m) long.

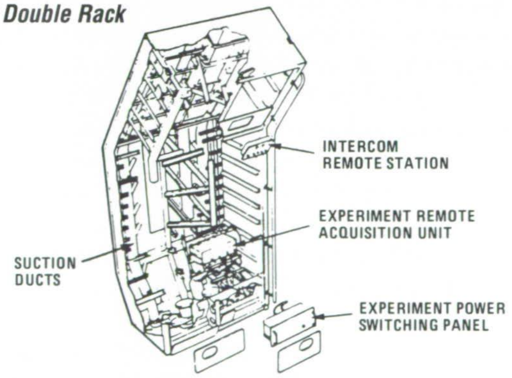
Equipment racks line both sides of the module and provide a universal mounting structure for experiment and system hardware. Racks come in single and double widths. A single rack accepts laboratory-standard 19-in. (0.483-m) panels. Double racks can accommodate equipment twice as wide or can be converted to the equivalent of two single racks by installing a rack center frame. Up to six double racks and four single racks are available for experiments in the long module. The short module accommodates up to two double racks and two single racks.

The module core segment includes a control center rack and a workbench rack. The control center rack contains several important components of the Command and Data

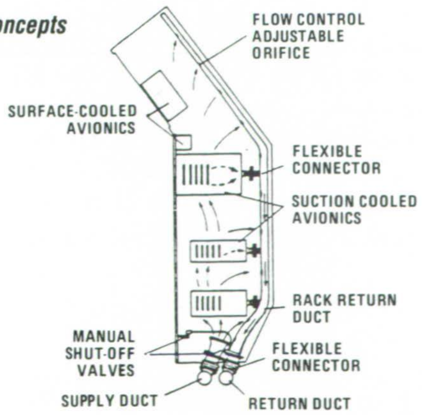


Spacelab Module Features

Experiment Double Rack



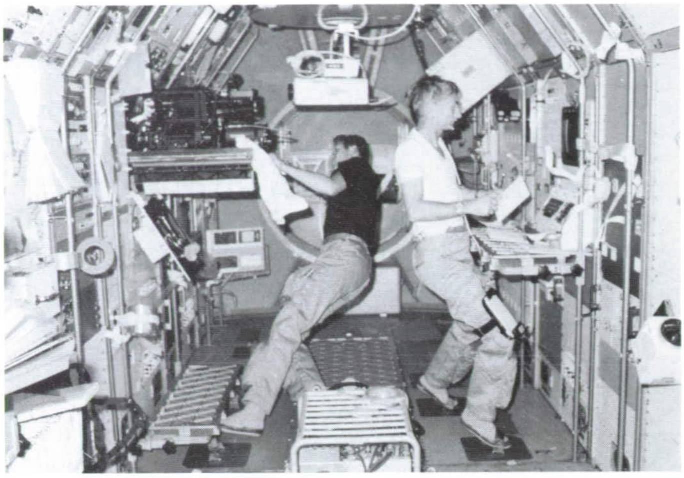
Rack-Cooling Concepts



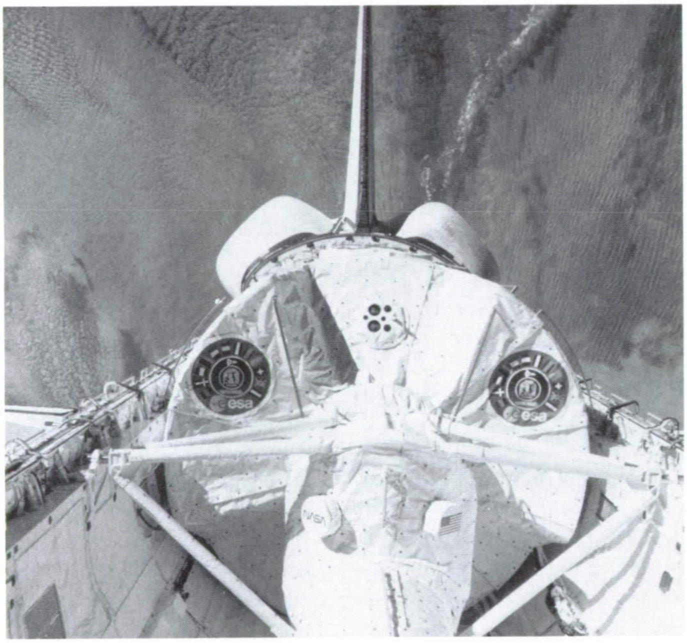
Management System; the workbench rack provides a work space for the crew. In addition, Rack 4, located next to the control center rack, is occupied largely by video and other system equipment.

Spacelab equipment racks are carefully engineered to achieve high strength and low weight. Single racks can carry up to 640 lb (290 kg) of equipment in an available volume of 30 ft^3 (0.85 m^3). Double racks can carry up to 1,280 lb (580 kg) with the center frame inserted and 1,060 lb (480 kg) with the frame removed; the available volume is 58 ft^3 (1.64 m^3).

Spacelab racks contain provisions for power, data, and environmental control interfaces. Electrical power for experiments is available from an Experiment Power Switching Panel (EPSP) located at the base of each rack. This switching panel has outputs for both primary 28 Vdc power and a limited amount of ac power (three phase, 117/203V, 400 Hz). Major power users can be connected to Experiment Power Distribution Boxes (EPDBs) under the floor. Near the EPSP at the rear of each rack is a mounting location for a Remote Acquisition Unit (RAU), the Spacelab signal interface unit that provides access to Spacelab experiment computer services. RAUs are installed as needed and are typically shared among several adjacent racks. Air suction ducts are built into the rear part of each rack, and air cooling is provided to experiment units connected to this ducting. Front panels must be installed to permit satisfactory performance of this cooling loop. Liquid cooling can be provided to experiment equipment by connecting a water loop to a heat exchanger located in Rack 4 adjacent to the control center rack.



A long module contains up to 12 racks for instruments and Spacelab systems. Once on orbit the flightcrew unstows equipment and conducts experiments much like they would in a ground-based laboratory.



The Spacelab long module has been used on several flights. Upcoming missions will use it primarily for life sciences and materials science studies.

Spacelab Optical Viewport Characteristics

Optical Characteristics	Viewport Performance
Wavefront RMS Error	$\lambda/50$ @ 633 nm
Transmission Bandwidth	400 to 920 nm
Average Transmission	91% (400 to 700 nm) 75% (700 to 900 nm)
Peak Transmission	95% @ 683 nm 95% @ 532 nm
Clear Aperture Diameter	8 in. (20.3 cm)
Window Construction	3-Panes (Achromatic Wedge)

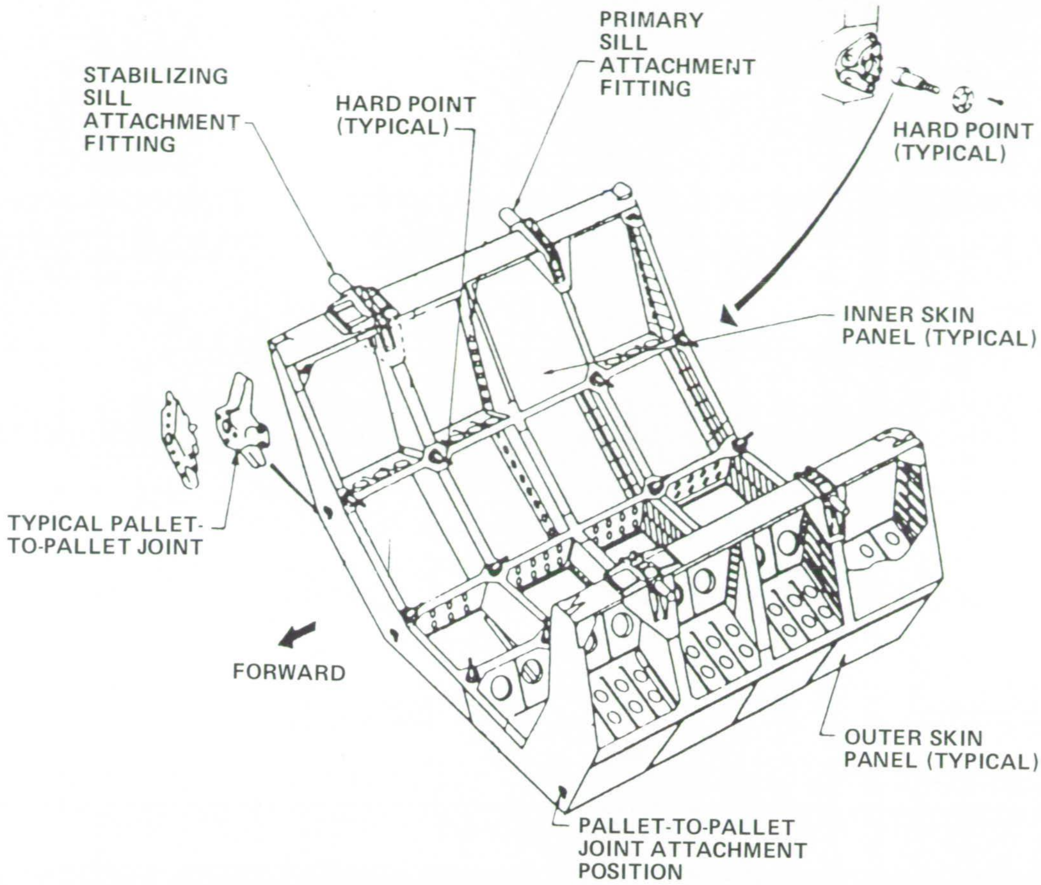
Other locations for science equipment are the center aisle of the main floor and the overhead and rack-mounted stowage containers. The center aisle envelope is 55 in. (1.40 m) high through most of the module, 25 in. (0.64 m) high in front of the control center rack, and 24 in. (0.60 m) wide throughout. Equipment mounts to attachment points and loading is permitted up to 60 lb/ft (90 kg/m) of center aisle length. A full complement of power, data, and environmental control services can be made available. Up to eight rack-mounted stowage containers are provided for investigator use; they are 11.2 in. (0.284 m) tall, 15.7 in. (0.399 m) wide, and 19.4 in. (0.493 m) deep and can hold up to 55 lb (25 kg) of equipment. Up to fourteen overhead stowage containers also are available. Overhead stowage containers are larger than the rack containers: they are 20.5 in. (0.521 m) x 20.4 in. (0.517 m) x 11.9 in. (0.302 m) and can hold up to 44 lb (20 kg).

Film can be stored in both the overhead and rack-mounted stowage containers by installing a film storage kit consisting of sheet-metal separators. The kits include sufficient separators to equip four overhead containers and four rack-mounted containers.

A high-quality viewport, the Spacelab Optical Viewport, is available on a mission-dependent basis. It contains three panes of fused silica and provides an 8-in. (20.3-cm) diameter clear aperture with peak transmissivity of 95%. A manually operated outer cover provides mechanical and thermal protection when the viewport is not in use. The viewport assembly installs in an adapter plate that can be mounted in the 51.2-in. (1.3-m) diameter flanged opening at the top of either module segment (core or experiment). These openings are otherwise closed with cover plates. The viewport adapter assembly can also be installed in the aft end cone for conducting experiments in coordination with pallet-mounted equipment.

Standard quality viewports are also available. One of them is permanently located in the aft end cone. Another can be installed on top of the module on a mission-dependent basis. The standard window element is somewhat larger than the optical window but the respective viewport assemblies are interchangeable.

Experiment equipment can be mounted at a viewport in two ways. Three safety cover attachment points in the viewport flange can support equipment weights up to 55 lb (25 kg). Handrail holes in the adapter plate can support up to 110 lb (50 kg).



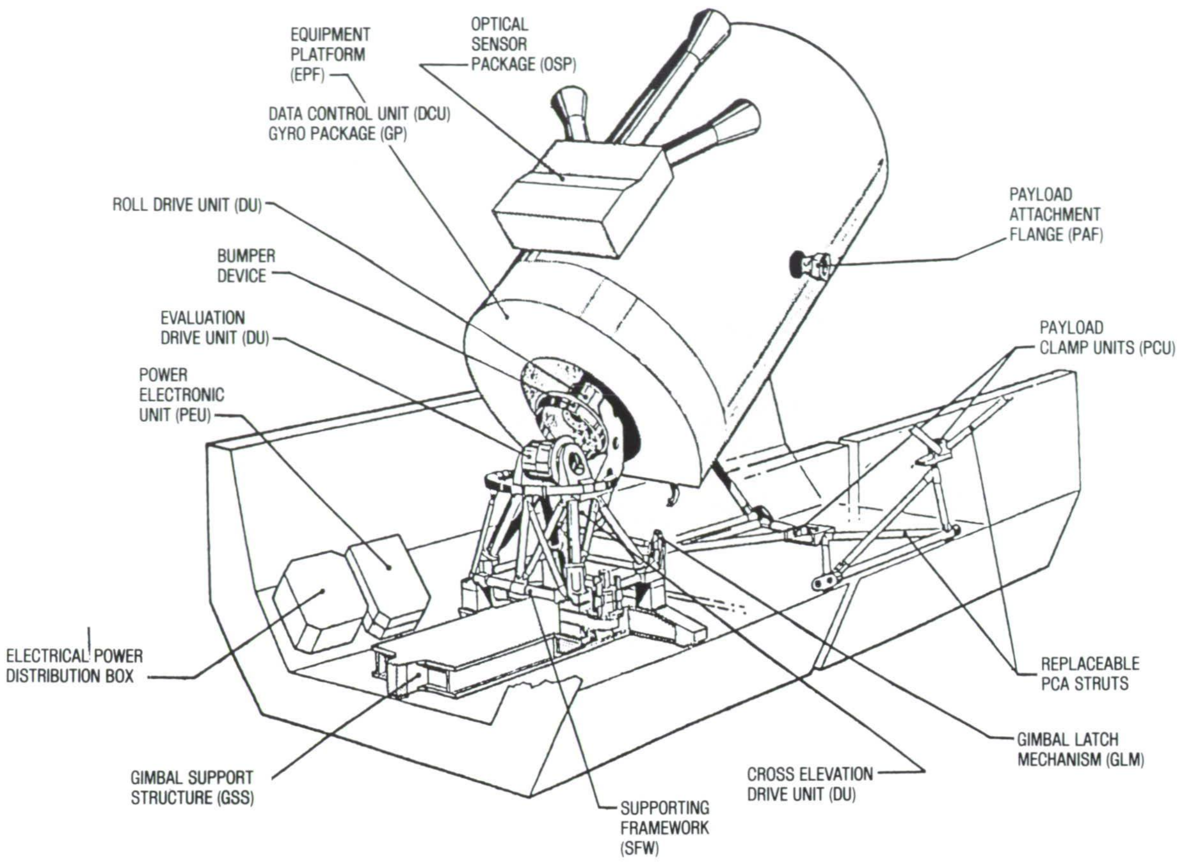
Hardpoints and skin panel inserts provide for user hardware attachment

Pallet Features

The Spacelab pallet is a U-shaped, aluminum, aeronautical shell fitted with honeycomb skin panels. It contains five cross frames (four primary and one secondary) connected by a number of longitudinal elements, including a keel. The pallet is 9.5 ft (2.88 m) long and has inboard cross dimensions of 5.8 ft (1.78 m) at the floor and 13 ft (3.95 m) at the sill. A single pallet has a load carrying capability of 6,350 lb (2,880 kg) with the igloo installed and 6,850 lb (3,110 kg) without. Two and three pallet trains have total load capacities of 11,000 lb (5,000 kg).

Pallet construction governs the attachment provisions for experiment and system equipment. Light-weight equipment and support brackets for Freon lines and cabling can be mounted directly to the inner surface skin panels. Threaded inserts arranged in a 5.5 in. (140 mm) square grid pattern provide the means for attachment and are installed as needed. Each panel is capable of supporting a uniformly distributed total load of up to 10.2 lb/ft^2 (50 kg/m^2). To mount large or heavy payloads, standard hard-point assemblies can be fastened to the intersection of the U-shaped cross members and longitudinal connecting members. Up to 24 hardpoints can be installed on a pallet.

Electrical power and data services available on the pallet are similar to those offered in the module. However, the environment in the cargo bay dictates a different approach to thermal control and both active and passive measures are used to keep temperatures within the desired range. When the pallets are flown with or without the module, a Freon cooling loop is available that may serve as either a heat sink or source. Elements of system and experiment equipment are mounted on coldplates as required. Support structures are installed to provide a coldplate mounting base and to provide for equipment attachment. These support structures contain threaded inserts in a 2.76 x 2.76 in. (70 x 70 mm) grid, and the coldplates contain a matching pattern of through holes. Standard ESA coldplates are 19.7 x 29.5 in. (500 x 750 mm) in size and can be located at any pallet panel position. Passive measures, such as special paint and multilayer insulation tents, are also elements of the pallet thermal control concept.



Instrument Pointing System

Performance Capabilities of the Instrument Pointing System

Performance Category	In the 2 axes perpendicular to the experiment line of sight	About the roll axis
Pointing accuracy of the experiment line of sight	2 arc sec	20 arc sec
Quiescent stability error	1.2 arc sec	3 arc sec
Man-motion disturbance	4 arc sec (peak)	15 arc sec (peak)

Values based on a 4,400-lb (1,996 kg) payload with center of rotation directly above Orbiter

Instrument Pointing System (IPS)

Fine pointing is a unique Spacelab capability not provided by other carriers. The Spacelab Instrument Pointing System (IPS) is a three-axis, optically aided, gyro-controlled pointing mount that can support a broad range of user requirements for stellar, solar, and landmark tracking. It can point to targets with an accuracy of 2 arc sec. Pointing stability is 1 arc sec under quiescent conditions or 4 arc sec under disturbed conditions.

A payload attachment ring provides a standardized mounting interface. Cruciform structures have been built for the Spacelab 2 and Astro 1 missions to facilitate the attachment of telescopes and supporting electronics. During launch and landing, the attachment ring separates from the gimbals, and the pointed payload is supported by a Payload Clamp Assembly (PCA). There are currently three PCA configurations. Payload assemblies weighing up to about 6,600 lb (3,000 kg) can be accommodated, although the IPS gimbals have enough torque to drive even larger payloads.

Spacelab power and data services are carried across the gimbals by IPS wiring harnesses. Both primary dc power (3 buses at 200 W each) and experiment-essential power are available. Data interfaces provide access to the experiment computer, high rate multiplexer, and closed circuit television system. Spacelab active thermal control is not available on the IPS. Integrated radiator systems using heat pipes were developed for Spacelab 2 and Astro 1 to facilitate heat rejection and better control the thermal environment.

Stability control of the IPS is based on a rate-integrating gyro package located on the outer gimbal. An optical sensor package is used to correct for gyro drift and to provide an absolute attitude reference. For stellar pointing, this package consists of one boresighted fixed-head star tracker and two skewed fixed-head star trackers. For a solar mission, the boresighted star tracker is reconfigured as a sun sensor. The IPS

control electronics can accept user-provided attitude commands and error signals. An image motion compensation system was developed for Astro 1 to improve instrument pointing stability.

Overall control of the pointing system during normal operations is exercised from a Spacelab data display unit and keyboard via the subsystem computer. Software packages covering all normal IPS functions from prelaunch checkout to prelanding payload retraction, reference guide star tables, and the planned observational sequence are all stored in the Spacelab data system.

Spacelab Command and Data Management System

The Spacelab Command and Data Management System (CDMS) serves three primary purposes: to control operations automatically by preprogrammed commands, to receive and execute real-time commands from the ground or from the crew in the Orbiter or Spacelab, and to process, display, store, and transmit data from Spacelab systems and experiments. The CDMS uses the Orbiter's telecommunications service to transmit data, receive commands, and maintain audio and video contact with the Payload Operations Control Center.

The heart of this Spacelab system is a set of three MITRA 125/MS computers with main memory capacity of 64K 16-bit words. One of these, the Experiment Computer (EC), activates, controls, and monitors payload operations and provides low-rate experiment data acquisition and data handling. After mid-1990, missions will fly with IBM AP-101/SL computers which use the same operating system as the MITRA but offer improved performance.

User instruments interact with the experiment computer through Remote Acquisition Units (RAUs). The RAUs connect to the CDMS data bus and provide a set of serial, discrete, and analog interfaces for data acquisition and commanding. All communications between the RAUs and the experiment computer are buffered by an Input/Output (I/O) unit.

Crew interaction with the CDMS occurs through computer terminals called Data Display Systems (DDSs). Each DDS includes a keyboard and a three-color video screen for data display in both text and graphic form. The DDSs connect to the Experiment Computer I/O (ECIO) unit, and up to three may be used on a mission.

Experiment computer memory loading is accomplished from a tape recorder called the Mass Memory Unit (MMU). This unit provides the initial program load for the experiment computer and stores various files, timelines, and displays. Approximately half of the unit's storage capacity is available for software and data that support Spacelab experiments.

Computer programs that run on the experiment computer are either part of the Experiment Computer Operating System (ECOS) or are Experiment Computer Applications Software (ECAS). ECOS provides such general services as activation, monitoring, manual and timelined commanding, and deactivation of experiment hardware as well as acquisition and downlinking of experiment data. ECAS is special mission software dedicated to the direct support of payload experiments. Programs for modeling the geomagnetic field environment as a function of orbit position and for custom data and graphics display are examples of ECAS.

High rate data handling is another important aspect of the Spacelab CDMS. Serial data from up to 16 user instruments and from the Spacelab computers are consolidated by the High Rate Multiplexer (HRM). The multiplexer output is routed to the Orbiter Ku-band communications system at rates up to 48 Mbps for real-time downlinking or to the High Data Rate Recorder (HDRR) at rates up to 32 Mbps for temporary storage. The recorder is used to buffer the multiplexer output during satellite link non-coverage times. The recorder is played back during satellite transmissions with the recorded data multiplexed for downlinking with new real-time user data.

Other Spacelab CDMS services include Closed Circuit Television (CCTV), onboard time data, and voice communications. The Spacelab CCTV system is simply an extension of the Orbiter CCTV system. Two Orbiter-type television cameras are used in the Spacelab module, and provisions exist for other payload television cameras that are part of experiment equipment. For pallet-only missions, one to three payload television cameras can be accommodated.

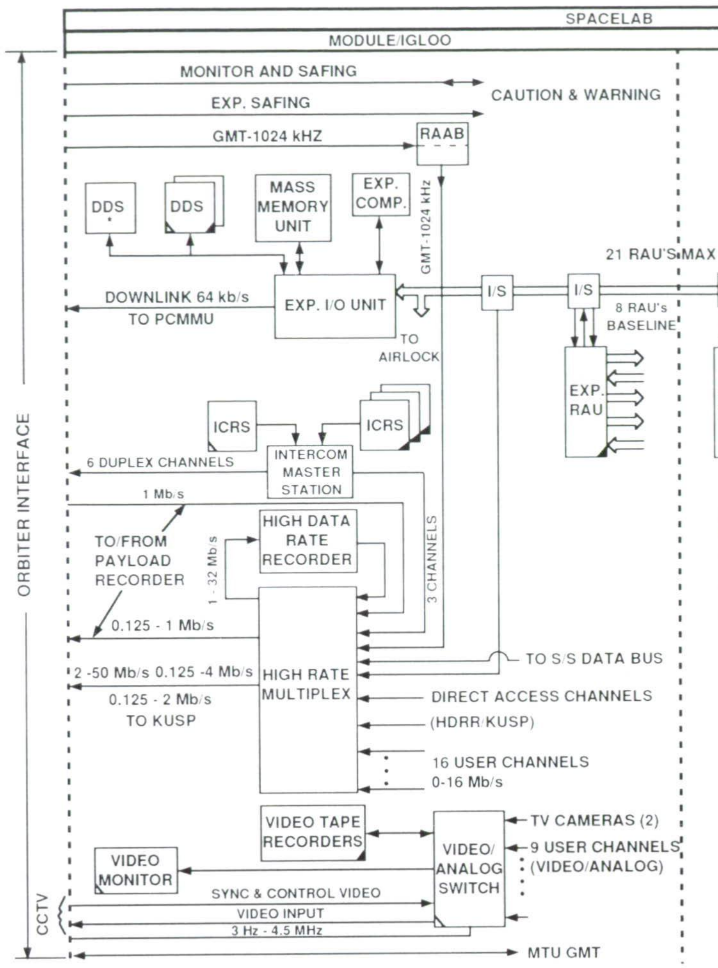
Video images can be displayed on television monitors onboard Spacelab or on the Orbiter aft flight deck. At the same time, they can be routed to Orbiter or Spacelab video tape recorders or they can be downlinked over Ku-band Channel 3 for display on the ground. CCTV permits real-time participation by engineers and scientists in payload operations but limits simultaneous downlinking of digital data (on Channel 2) to 2 Mbps.

On Spacelab module missions, video instrumentation tape recorders and standard VHS recorders are available as mission-dependent equipment. Crewmembers can change tapes as a part of on-orbit experiment procedures.

Spacelab receives "onboard time" from the Orbiter Master Time Unit (MTU) through the timing buffer and distributes two different types of time information. Greenwich Mean Time (GMT) with a resolution of 10 ms is available via the RAU serial command channels and is also inserted into high rate multiplexer data frames. A 1024 kHz User Clock Signal (UCS) and a UCS update signal provide a fine scale time reference. The user clock and clock update signals are intended to increment and reset a user-provided counter. The contents of this time counter can be used by the Spacelab experiment computer to time tag experiment event data with a relative accuracy of 10 μsec.

In addition to the RAU time interfaces, GMT and Mission Elapsed Time (MET) can be made available directly from the Orbiter Timing Buffer at special connector brackets. The signal format is a modified Interrange Instrumentation Group B (IRIG-B).

Spacelab provides some additional audio communication capability beyond what is offered by the Orbiter. Voice channels are routed to the HRM and CCTV system. The HRM voice inputs are digitized and multiplexed into the downlink for direct communication with ground stations and for voice



ABBR.	LEGEND
CCTV	CLOSED CIRCUIT TELEVISION
DDS	DATA DISPLAY SYSTEM (COMPRISING SL DDU KB)
DDU/KB	DATA DISPLAY UNIT KEYBOARD
GMT	GREENWICH MEAN TIME
HDRR	HIGH DATA RATE RECORDER
ICRS	INTERCOM REMOTE STATION
I/O UNIT	INPUT/OUTPUT UNIT
I/S	INTERCONNECTING STATION
KUSP	KU-BAND SIGNAL PROCESSOR
MDM	ORBITER MULTIPLEXER/DEMULTIPLEXER
MTU	MASTER TIMING UNIT (ORBITER)
RAAB	REMOTE AMPLIFIER & ADVISORY BOX
RAU	REMOTE ACQUISITION UNIT
PCMMU	PCM MASTER UNIT
•	AFT FLIGHT DECK

Command and Data Management System Block Diagram for Spacelab

annotation of scientific data. For module missions, uplink and downlink voice signals are digitized. For all-pallet missions, only downlink voice is digitized.

A limited number of Orbiter ancillary data parameters are available to user instruments in real time. The Orbiter computer generates state vector and corollary data and transmits the data to Spacelab. These data may be routed to experiments via the RAUs. They may also be accessed by applications software for use in instrument control.

Spacelab Pallet System (SPS) Igloo Pallet

The SPS Igloo Pallet is a baselined configuration of the Spacelab pallet system. It offers a standard set of structural interface provisions and can fly in the mixed cargo mode. It is comprised of a two-pallet train and an igloo; the Instrument Pointing System may be installed as a user option.

From a user perspective, this pallet system is very similar to a Spacelab dedicated pallet configuration. Certain volume constraints have been defined to account for space occupied by system hardware. Also, the SPS Igloo Pallet operates under reduced power and energy resources to allow for sharing with other payloads.

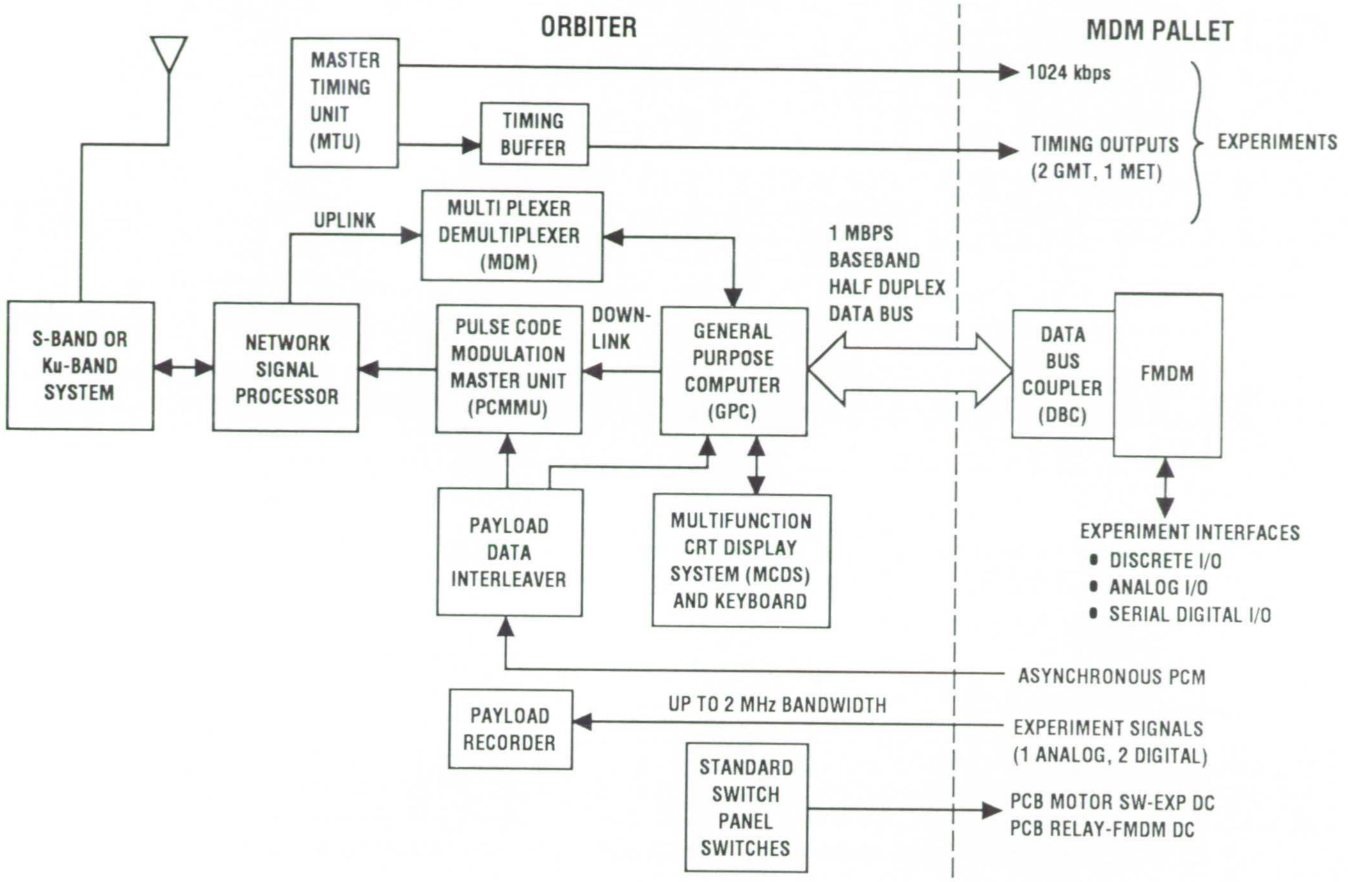
▸Spacelab-Derivative Mixed Cargo Carriers

If your experiment does not require the full range of services available on Spacelab, you may find greater scheduling opportunity and flexibility on a mixed cargo carrier. Mixed cargo carriers are generally compatible with the level of power and signal resources guaranteed under the standard quarter-section allocation but often can handle a higher level of resources if available.

From your standpoint, a significant difference between mixed cargo carriers and Spacelab lies in the command and data-handling accommodations. On Spacelab, instruments interact with the self-contained and highly capable Spacelab Command and Data Management System. On mixed cargo carriers, the instrument command and data handling accommodations reflect more directly the standard avionics services offered by the Orbiter. Other areas of difference include crew availability, power and energy resources, and downlink rate.

The Multiplexer/Demultiplexer (MDM) Pallet

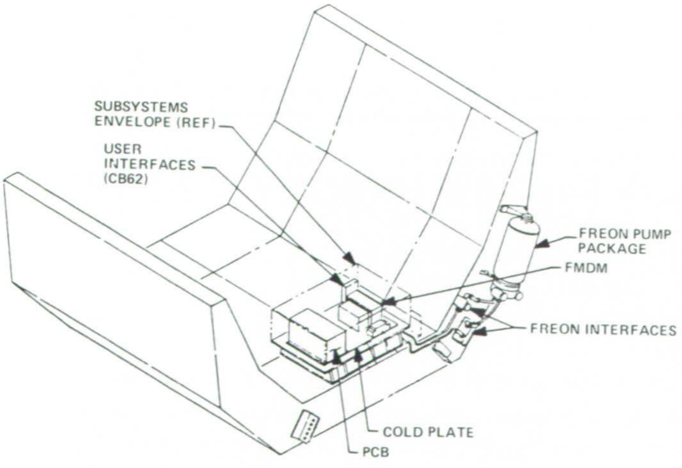
The Multiplexer/Demultiplexer (MDM) Pallet system was used to accommodate the first two Shuttle science missions, OSTA-1 and OSS-1. It is based on a single Spacelab pallet without the igloo. Major system elements include a Flexible



Typical Mixed Cargo Command/Data System Accommodations

Multiplexer/Demultiplexer (FMDM), a power control box, and a Freon pump package.

The forward end frame of the pallet has provisions for mounting the Freon pump package, fluid lines, and wiring

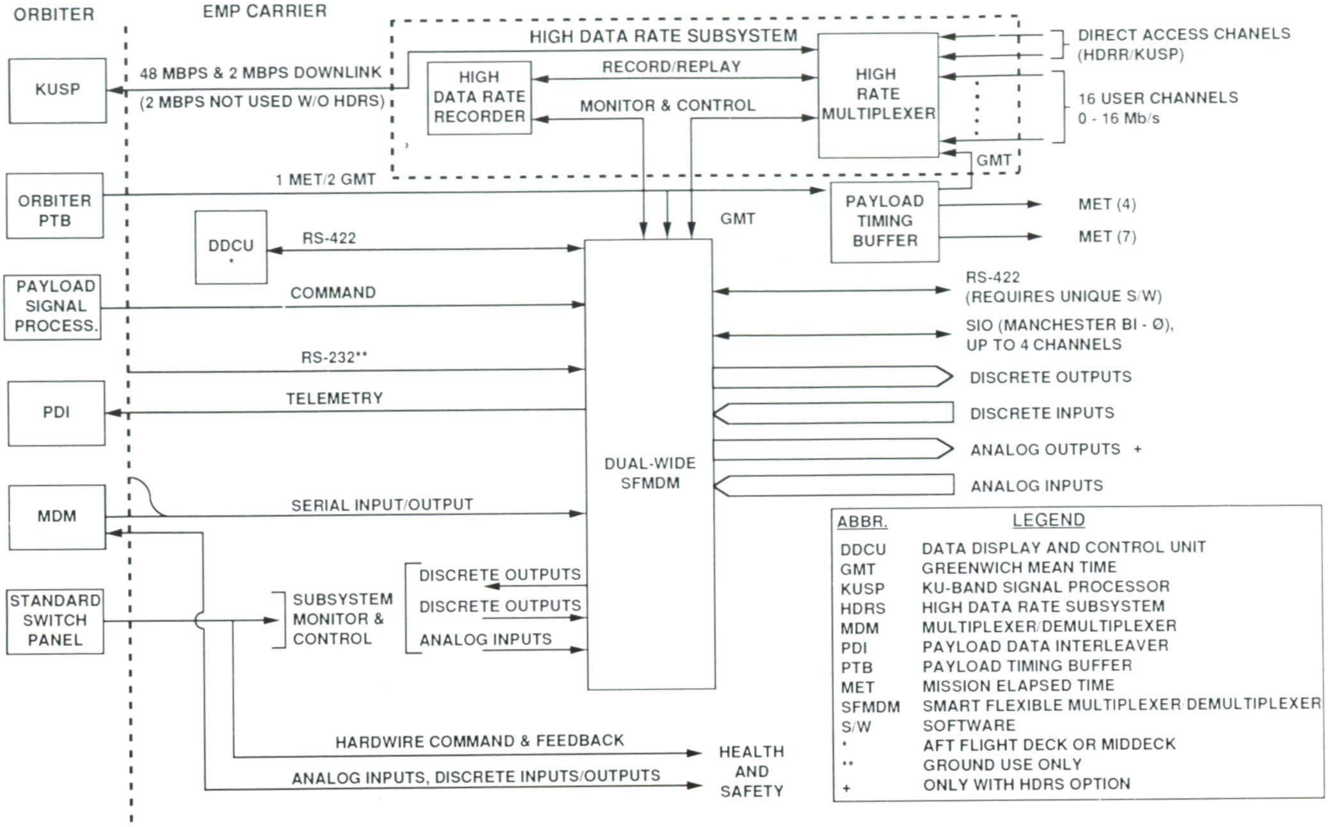


MDM Pallet Subsystem Equipment Arrangement

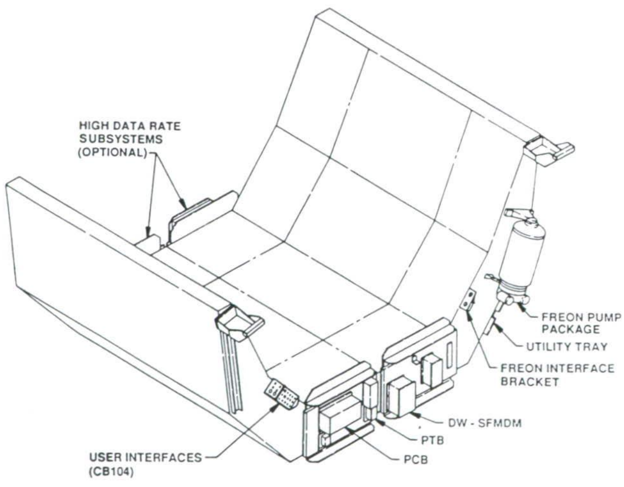
harnesses that interface with the Orbiter. The avionics units are mounted on a cold plate assembly located on the pallet floor. The remainder of the pallet/payload envelope is available for user equipment.

The FMDM is a carrier-provided bus terminal unit similar to an Orbiter MDM but with interchangeable input/output modules. It provides access to command and data handling services of the Orbiter general purpose computer and offers a variety of discrete, analog, and serial input/output channels. Other data services, standard or optional, are available to users through direct interfaces. These services include Greenwich Mean Time (GMT) and Mission Elapsed Time (MET) from the Orbiter master timing unit, data downlink through the Payload Data Interleavor (PDI) (one port standard, others negotiable), and data recording on the payload recorder (one analog and two digital channels standard).

A power control box provides power distribution and circuit protection. Power control is accomplished from the aft flight deck through either the standard switch panel or through the Orbiter data bus system. Coldplates are available for instruments requiring active cooling.



Command and Data Management System Block Diagram for the Enhanced MDM Pallet



Subsystem Equipment Arrangement for the Enhanced MDM Pallet

Enhanced Multiplexer/Demultiplexer Pallet (EMP)

This carrier represents a significant enhancement of the MDM pallet system, and with the exception of fine pointing, it offers a level of capability approaching that of the Spacelab Igloo Pallet. The EMP data system includes an autonomous payload controller, a dedicated keyboard/display unit, and a high data rate option using the Spacelab high rate multiplexer and recorder. In addition, all major system components are mounted on the pallet forward and aft frames, leaving almost the entire inner surface available for user equipment.

The heart of the EMP data system is a Dual Wide-Smart Flexible Multiplexer/Demultiplexer (DW-SFMDM). This unit serves as an integrated interface to a number of mixed cargo data services. These include telemetry downlink through the Payload Data Interleaver (16 kbps standard) and command uplink through the Payload Signal Processor. The DW-SFMDM provides command decoding, verification and distribution, and low-rate data acquisition and multiplexing.

The EMP Data Display and Control Unit (DDCU), a GRiD computer, is located in the aft flight deck or middeck and interfaces directly to the DW-SFMDM. It provides onboard control and monitoring of experiment functions and monitoring of EMP system functions. Standard DDCU software services include limit monitoring, measurement display, crew-initiated commands, timelined commands, and time-executable command loads. User application tasks can also be run on the display

unit, and DDCU generic software gives tasks access to experiment data and to Orbiter state vector, attitude, and time data.

EMP power and active thermal control systems are equivalent to those of the MDM pallet. The standard mixed cargo power allocation is 1.75 kW maximum continuous. EMP systems use approximately 165 W without the high data rate option and 550 W with the option. Up to four system coldplates are required for EMP avionics equipment and additional coldplates are added for user equipment as required.

▶Quick-Reaction/Standard Interface Carriers

Several low-cost, quick-reaction carriers have been developed that are ideal for users whose instruments do not require the customized interfaces and extensive services available on pallet-based systems. These more economical alternatives include Hitchhiker-G, Hitchhiker-M, and the MPESS-A and MPESS-B carriers.

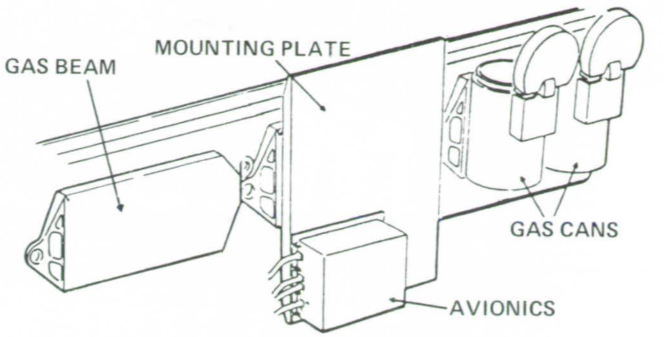
The attributes of low mission cost and short integration cycle go hand-in-hand and are achieved in two ways. By offering a fixed set of user interfaces, reconfiguration of the carrier and ground support equipment between missions can be minimized or avoided. Furthermore, by requiring users to design equipment directly to those interfaces, the long lead times and expenses associated with the development of unique integration equipment can also be avoided.

The Hitchhiker Program

The Hitchhiker Program was initiated by the NASA Office of Space Flight to provide a quick-reaction carrier capability between the Get Away Special (GAS) and the MDM pallet. Two basic configurations have been developed—Hitchhiker-G and Hitchhiker-M. These carriers are managed by GSFC. Hitchhiker-G is a family of components designed to mount small payloads to the side of the Orbiter with minimum total payload weight. Hitchhiker-M is intended for somewhat heavier payloads and uses an across-the-bay (bridge) structure. Hitchhikers are normally carried in bays 2 and 3 near the forward end of the payload bay. They can accommodate up to six user instruments, and both types offer identical electrical interfaces and services.

Hitchhikers are flown as secondary payloads under policies that pertain either to "small" payloads or to standard mixed cargo payloads. In general, secondary payloads may not interfere with primary payloads on the same mission. Under the small payload policy, specific additional restrictions apply to crew activities, power, payload bay location, etc., to simplify Shuttle integration and analysis and achieve short lead time requirements and increased manifesting flexibility. Even so, unique crew activity and attitude (pointing) requirements of a limited nature can usually be accommodated. Under the mixed cargo policy, investigators may negotiate the use of a variety of optional STS interfaces, resources, or activities at the expense of increased lead time and reduced manifesting flexibility.

The Hitchhiker-G mounting system can accommodate up to 750 lb (340 kg) of user equipment. A Get Away Special



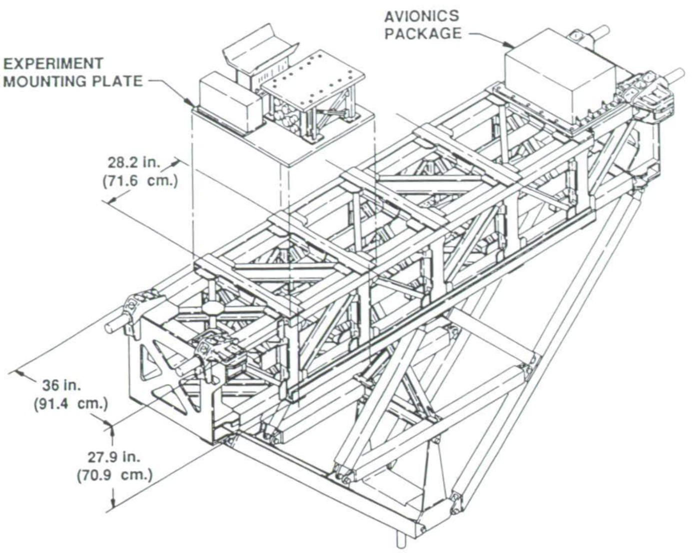
Hitchhiker-G offers users three mounting options.

(GAS) adapter beam is the structural foundation of Hitchhiker-G and provides for the attachment of other components to the side of the payload bay. Plates and canisters are included in the family of components to provide the user with three basic mounting options, depending on equipment size and weight.

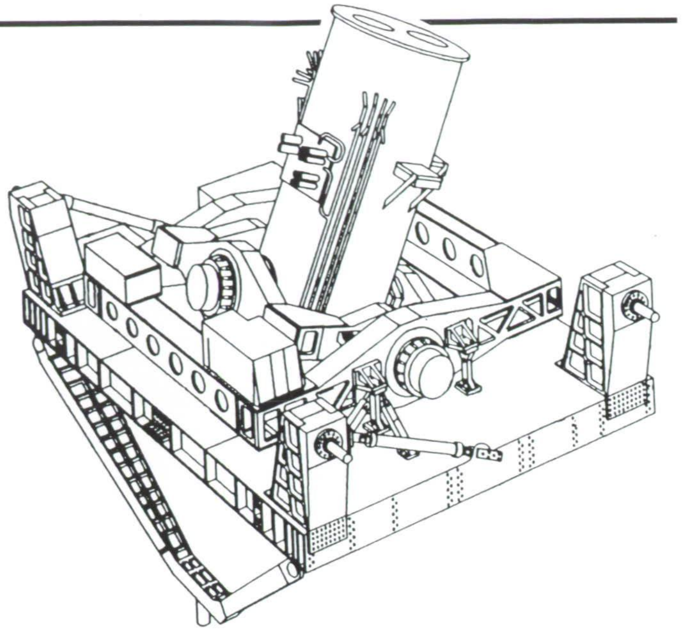
- **Direct Mounting** - Up to 750 lb (340 kg) can be accommodated by attaching the flight unit directly to a GAS beam.
- **GAS Container** - Two versions of GAS canister have been adapted for Hitchhiker-G. The standard GAS container provides a sealed environment (1 atm air or nitrogen) for up to 200 lb (91 kg) of experiment equipment within a volume 19.75 in. (50 cm) in diameter by 28.25 in. (72 cm) high. A motorized door container with mechanical interfaces and dimensions nearly identical to the standard container can accommodate up to 170 lb (77 kg) of equipment. Up to two canisters can be mounted on a GAS beam.
- **Plate Mounting** - Two types of mounting plates attach to the GAS adapter beam and provide a 2.756 in. (70-mm) grid hole pattern interface. A large plate (50 x 60 in./127 x 152 cm) can accommodate the avionics unit and up to 250 lb (113 kg) of experiment equipment or 500 lb (227 kg) without the avionics unit. A small plate (25 x 39 in./64 x 100 cm) can accommodate up to 100 lb (45 kg) of experiment equipment.
- **Combination Mounting** - Subject to approval by Hitchhiker Project management, certain combinations of the three mounting configurations can be used.

Hitchhiker-M uses the Multi-Purpose Experiment Support Structure (MPESS) carrier to accommodate up to 1,200 lb (544 kg) of user equipment. Each of the top and side surfaces of the MPESS contains four mounting locations. The top mounting locations (36 x 28.2 in./91 x 71.6 cm) can accommodate up to 380 lb (172 kg) each. The side mounting locations (27.9 x 28.2 in./70.8 x 71.6 cm) can support up to 170 lb (77 kg) each.

The Hitchhiker avionics unit normally connects to the small payload accommodations harness but can be connected to the standard mixed cargo harness for additional power and energy resources if necessary. The avionics unit provides standard electrical interfaces or "ports" for up to six instruments. It contains a microprocessor control unit, power switching



Hitchhiker-M Experiment Hardware Mounting Concept



Two-Axis Pointing System mounted on the TAPS Support Structure

equipment, a medium-rate multiplexer, and other interfacing functions.

Both Hitchhiker-G and Hitchhiker-M operate within the same Orbiter power and data envelopes. Users share 1.3 kW of electrical power, 4 kWh of energy per day (more may be negotiable), and a multiplexed medium-rate downlink channel of 1 to 1400 kbps (real time only). Each user port also offers an asynchronous 1200 baud downlink channel, an asynchronous 1200 baud uplink channel, IRIG-B, and several other command and data management services. Neither carrier offers active thermal control.

Primary control of Hitchhiker payloads is from the ground, and the basic data services allow investigators to interact with experiments during flight operations. Hitchhiker is activated and deactivated by the flight crew from a switch panel in the aft flight deck. This switch panel also provides an independent command path to control inhibits to any hazardous functions.

Hitchhiker-G payloads are integrated at GSFC, and system tests and an electromagnetic interference (EMI) test are performed. The integrated payload is then shipped to a KSC staging area for unpacking, inspection, and integration into the Orbiter. Hitchhiker-M payload integration is accomplished at KSC.

The Two-Axis Pointing System (TAPS)

The Two-Axis Pointing System is a center-of-gravity pointing mount that uses the flight avionics unit and ground support equipment developed for the Hitchhiker program. The gimbal assembly is supported by an across-the-bay carrier referred to as the TAPS Support Structure. This pointing mount includes a star tracker and a gyro package and can accomplish inertial or Earth-referenced pointing with an accuracy of up to 1.8 arc min. Gimbal range is approximately ± 20 deg about the Orbiter pitch and roll axes. Movement about the Z-axis (yaw) is accomplished by the Orbiter.

Primary control of TAPS flight operations is from the ground. Prior to launch the entire mission observing program will be preplanned and stored in the TAPS ground support equipment. A near real-time replanning capability allows scientists to adjust the observing program for off-nominal launch, unforeseen events, or targets of opportunity. A backup observing mode, activated by the flight crew, steps through an automatic timeline sequence in the event that TAPS cannot be commanded from the ground.

An auxiliary power unit has been developed for the TAPS to increase power handling capability and facilitate pre-launch operations at the pad by interfacing to the Orbiter T-O umbilical. The T-O umbilical provides a means of selectively powering and monitoring critical instrument functions such as cryogenic and vacuum systems without powering up other payload elements.

Multipurpose Experiment Support Structure (MPESS) A and B

The MPESS-A and MPESS-B carriers are an outgrowth of the original Materials Science Laboratory (MSL) carrier. They are designed to meet the need of the microgravity science community for a low-cost, quick-reaction carrier system. They offer a full complement of power, data, and thermal control services; as with other quick-reaction programs, investigators furnish mounting plates, cables, and plumbing to connect to the interfaces provided.

MPESS-A is an enhanced version of the MSL and offers standard accommodations to three user payload elements within a single mixed cargo resource allocation. MPESS-B adds a second support structure to MPESS-A for additional load carrying capability. It provides for the integration of up to six payload elements and takes full advantage of the available system capabilities. MPESS-B is the primary system configuration for the foreseeable future and is being used for the U.S. Microgravity Payload (USMP) series of missions.

Quick-Reaction Standard Interface Carriers:

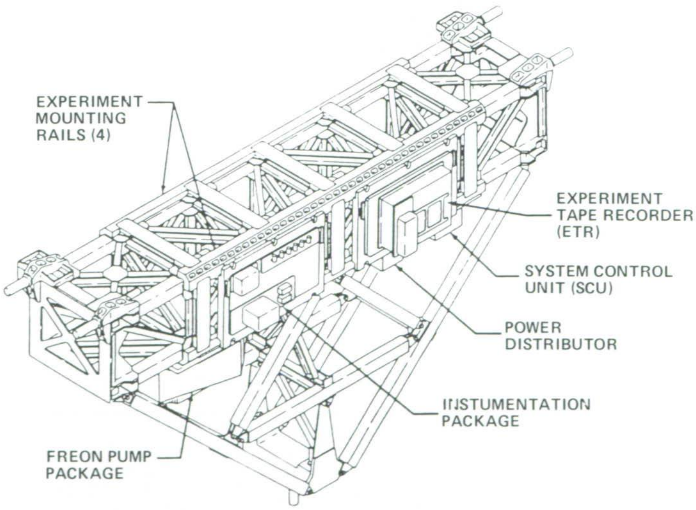
		HITCHHIKER-G	HITCHHIKER-M	MPESS-A
Structure		GAS cans + 50- x 60-in. (1.27 x 1.52 m) plate + GAS beam	MPESS	MPESS*
Subsystems		Avionics Unit	Avionics Unit	System Control Unit Power Control Box Freon loop Recorder Accelerometer
Capability				
	No. Instruments	Up to six	Up to six	Up to three†
	Load	750 lb (340 kg)	1,200 lb (544 kg)	2,000 lb (907 kg)†
	Power	1,300 W	1,300 W	1,400 W
	Telemetry	8 kbps/1.4 Mbps	8 kbps/1.4 Mbps	16 kbps
	Data Storage	—	—	~ 2.6×10^{10} bits
	Control	POCC	POCC	POCC
	Heat Rejection	Passive	Passive	Freon loop
Flight Frequency		2/year	1/year	1/year
Additional Info.		HQ/MK GSFC/741.2	HQ/MK GSFC/741.2	HQ/EM MSFC/JA01
Availability		Now	Now	Now

* MPESS-B uses 2 structures.
† MPESS-B capability is approximately double MPESS-A.

Mounting rails are provided along the edges of the top and sides of each MPESS. Each rail contains a linear pattern of 0.375 in. (9.53 mm) holes spaced on 2.756 in. (70 mm) centers running along the entire length for direct attachment of user hardware. Carrier-provided support plates are also available.

The central element of the MPESS-A or MPESS-B Command and Data Management System (CDMS) is the System Control Unit (SCU). The SCU is an intelligent payload controller and bus terminal unit. This unit receives and interprets commands from the crew or the ground through the Orbiter computer and issues commands to the systems and experiments. It also routes data to be recorded on the Experiment Tape Recorder (ETR) and downlinked through the Payload Data Interleaver (PDI). Limited data may also be displayed for crew monitoring. The ETR is a part of the carrier data management system. Experiment and carrier data are recorded during the mission and are played back for distribution and analysis after the Orbiter has landed. Investigators have the option of time tagging their data with either GMT or MET through a direct interface with the Orbiter Timing Buffer.

Acceleration data are available real time or postflight via the Space Acceleration Measurement System (SAMS). Depending on the experiment complement, there are several options available when determining frequency ranges and



MPESS-A configuration showing component mounting (MPESS-B uses the same subsystems but includes a second MPESS.)

sampling rates. The measurement data are recorded on optical disks for postflight analysis. Active thermal control is provided by a single-phase, liquid Freon coolant loop. The investigator has the option of mounting to a coldplate or interfacing to the Freon loop directly.

▶Special Small Payload Accommodations

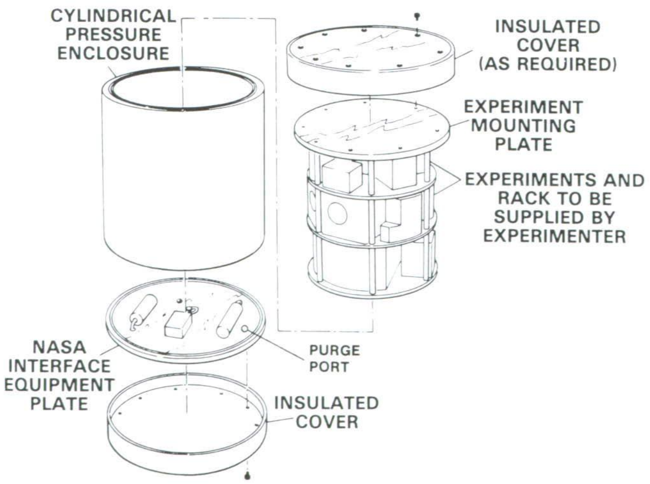
Special accommodations for small instruments that are highly self-sufficient are provided by the Get Away Special (GAS) carrier and the locker compartments located in the Orbiter middeck. While basic services are very limited, the low flight cost, high flight frequency, and short lead time provide an excellent opportunity to conduct simple exploratory and proof-of-concept research before developing more elaborate flight equipment.

The Get Away Special (GAS)

The GAS carrier system is managed by GSFC. It offers the easiest, most economical means of flying experiment equipment in the Orbiter payload bay, provided the equipment can meet the volume, safety, and self-sufficiency constraints. A limited set of switch functions is available for experiment control, but users must provide data storage and electrical power. A scientific, technology development, or test experiment will be accepted on a first-come, first-served basis; at present, about 70 flight opportunities are planned per year.

The principal element in the GAS concept is an aluminum canister that provides complete containment for experiment equipment, thus making safety assurance comparatively easy. Normally the canisters are mounted to the side of the cargo bay. A GAS bridge has also been developed that spans the cargo bay and holds from 5 to 12 standard canisters.

Standard GAS containers come in two sizes. The larger one provides 5 ft^3 (0.14 m^3) of user volume in an envelope 19.75 in. (50.16 cm) in diameter by 28.25 in. (71.75 cm) high. It can accommodate up to 200 lb (91 kg) of experiment equipment. The smaller container is the same diameter as the large one but the user envelope is only half as high. It can accommodate



Get Away Special Container Concept

up to 60 lb (27 kg) or 100 lb (45 kg) of payload weight depending on the investigator's launch services agreement.

The circular end plate at the top of a GAS container is the experiment mounting plate. The inner surface has a pattern of threaded inserts adaptable to mounting a variety of hardware. Users commonly attach a rack structure to efficiently utilize the available volume. In this case adjustable bumpers are generally required at the free end of the rack to provide lateral stabilization against the canister wall. The experiment mounting plate also contains two purge ports and a battery box vent turret as required.

The bottom end plate is the interface equipment plate. It contains the electrical control connections and ports for purging and pressure relief. It also provides mounting for NASA interface equipment such as command decoders and pressure-regulating systems.

As currently designed, a GAS canister can be flown with about 1 atmosphere of dry nitrogen or air, evacuated during ascent and repressurized during reentry, or evacuated before launch. The experiment mounting plate can act as a thermal absorption or radiation surface and may or may not be insulated, depending on investigation requirements. The bottom and sides of the container are always insulated.

Three latching relays provide toggle switch control for instrument activation/deactivation and operational mode changes. Commands are issued and verified by the crew through a hand-held encoder called the Autonomous Payload Controller (APC). The commands are sent "party line fashion" to all containers via a twisted shielded pair of wires and are interpreted within each GAS container by a control decoder. Latching relays in the decoder can switch up to 2 amps of current from a user-provided power source. A supplemental power contactor can switch two 25-amp circuits or a single 50-amp circuit.

Normally, an instrument using the GAS carrier is installed in the GAS canister about 2 months before launch, although attempts are being made to reduce this time. The instrument is not removed until about 2 weeks after landing; therefore an experiment requiring live specimens or requiring rapid access may be impractical unless special precautions are taken.

Throughout the program, engineers at GSFC have worked to increase GAS capabilities as customers request. For example, one investigator assisted NASA in developing a door in the top of the canister that can be opened in orbit. This configuration is now available to others as an option. For another investigator, a small antenna was mounted on top of the canister for transmission of amateur radio signals. In this mode, frequency and power constraints had to be met not only to comply with Federal Communications Commission rules but also to avoid interference with the Shuttle avionics and other payloads. In addition, GSFC has developed the ability to eject non-recoverable GAS payloads.

GAS equipment options include an interconnecting cable and a Motorized Door Assembly (MDA). The interconnecting cable provides a power and data transfer capability between two containers. The door assembly enables payloads to view

space through a protective window or be exposed directly to the space environment. NASA can provide either a fused silica window or a BK7 (Borosilicate Crown) window. These windows are designed to withstand normal GAS operating pressures. The experiment mounting plate for the door assembly is a ring with a 15.38 in. (39.0 km) diameter hole. It has a support capacity of 150 lb (68 kg) with a standard window installed and 160 lb (73 kg) without the window. Investigators should be aware that using a door with an open aperture significantly increases the verification requirements for safety certification and will entail finite element modeling, fracture mechanics analysis, materials control, and other steps not required for contained/sealed accommodation modes.

The capability to meet special requirements has been formalized in the Complex Autonomous Payload (CAP) Program. This program utilizes the GAS containers and optional hardware such as the open aperture door assembly and the satellite deployment mechanism. CAP payloads do not connect to Orbiter electrical services, but may require STS services such as pointing, crew activity, or late access in excess of those allowed in the GAS Program. As a result, longer lead times are required to coordinate operations planning and account for a more involved safety analysis and review process. Finally, CAP payloads are scheduled as secondary payloads on STS mission manifests, rather than on the "last minute" space-available basis afforded GAS payloads.

The Orbiter Middeck

The Orbiter middeck contains mounting space for 42 storage lockers that normally contain the crew food, clothing, and equipment. Unused lockers and/or their mounting spaces are made available for experiment equipment on a mission-by-mission basis. The availability of crew services, late preflight access, and early postflight access can be compelling reasons for locating experiment equipment in the middeck.

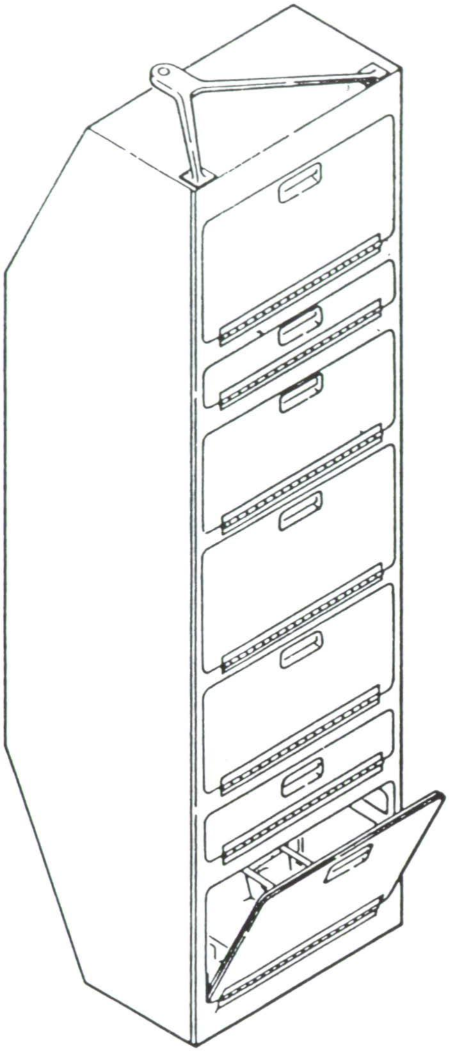
Crew Eating in Middeck Area

In addition to the locker volumes, there are other volumes that might be utilized for experiment equipment. These include the area occupied by the galley, the space above the forward locker matrix, and the volumes within the starboard closeout sections. Since special arrangements must be made, any requirement for the use of these storage spaces should be coordinated with the Transportation Services Division at NASA Headquarters.

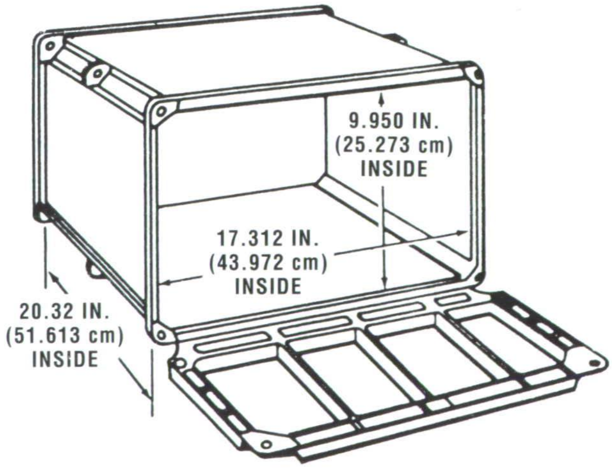
Each middeck locker may accommodate up to 54 lb (25 kg) of user equipment in 2 ft^3 (0.566 m^3) of stowage volume.

Get Away Special and middeck accommodations offer limited basic services but high flight frequency:

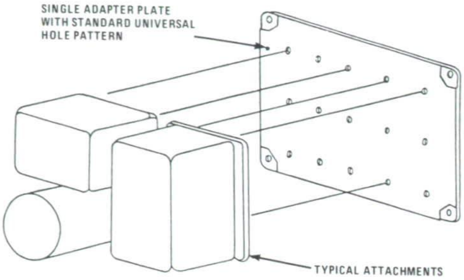
	GET AWAY SPECIAL	ORBITER MIDDECK	MAR
Structure	*Container: 19.8 dia x 28.3 in. (0.5 x 0.72 m) +19.8 dia x 14.1 in. (0.5 x 0.358 m)*	*Locker: 17.3 x 9.9 x 20.3 in. (4.39 x 0.25 x 0.52 m) + Single plate 18.1 x 10.8 in. (0.46 x 0.274 m) + Double plate 18.1 x 21.9 in. (0.46 x 0.556 m)*	*Rack: 16 ft^3 internal (0.45 m^3)*
Subsystems	*On/off only Time*	*Power Cable*	*Power Water Loop Interface*
Capability			
Load	*60,100, or 200 lb (27.2, 45.3, 90.7 kg)*	*30 to 120 lb (13.6 to 54.4 kg)*	*350 lb (160 kg)*
Power	*User-provided*	*5A at 28 Vdc*	*500 W at 28 Vdc*
Heat rejection	*Passive*	*60 to 90 W passive*	*1000 W water loop*
Data Handling	*User-Provided*	*User-provided*	*User-provided*
Control	*Autonomous Payload Controller (APC)*	*Front panel (User-provided)*	*Front panel (User-provided)*
Flight Frequency	*70 cans/yr*	*Each flight*	*Each flight*
Additional Information	*HQ/MC GSFC/740.3*	*HQ/MO JSC/TC4*	*HQ/MO JSC/TC4*
Availability	*Now*	*Now*	*1991*



Middeck Accommodations Rack with lockers installed



Individual Compartment of Middeck Accomodations Rack



Stowage and Mount Provisions — Single Adapter Plate

Full height and half height plastic trays, foam cushions, tray dividers, and elastic restraints are all standard elements of the stowage system. The lockers are designed to be packed solid, and there must be an isolator material between the locker walls and contents. Where trays cannot be used, stowed equipment should be designed to the size and shape of a full height or half height tray. Finally, access for power, cooling, or crew attention can be provided through a modified locker access door with three removable panels.

Under normal conditions, trays can be packed, transported to the Orbiter launch pad, and installed in lockers about 3 to 8 days before launch. To accomplish this, however, the flight hardware must be delivered approximately 1 month before flight. In unique situations, time-critical samples may be loaded late in the countdown.

Wire or cable support trays between the middeck habitable area and adjacent avionics bays provide a mounting structure for standard lockers. Each locker is attached to the wire tray structure by four long bolts. Lockers can be removed and single adapter plates, double adapter plates, or payload mounting panels can be installed to provide an attachment surface for non-locker hardware. The single and double mounting plates have a universal hole pattern suitable for attaching a range of unit sizes. The hole pattern of the payload mounting panel is better suited for locker-sized units. The weight capacity of the wire tray structure is 69 lb (31 kg) for a one-locker replacement and 120 lb (54 kg) for a two-locker replacement. These numbers include mounting plates and attachment hardware and assume a center of gravity (CG) location no more than 10 in. (25 cm) from the wire tray face. Maximum payload weight is CG dependent. Non-locker equipment should not extend beyond the locker door plane, approximately 21 in. (0.5 m) from the wire tray face.

System resources are limited. During on-orbit operations 115 W (5 amps) of nominal 28 Vdc power is available for periods of up to 8 hours. Three outlets are located in the middeck ceiling, and two are located in the galley floor. Standard cables are provided to route power from the ceiling outlets to user equipment. There are no provisions for interfacing to the Orbiter data system. If a tape recorder or computer is needed, it must be provided by the user. Heat rejection capacity is compatible with available power where forced circulation of

cabin air is employed; otherwise, the heat load in a standard stowage locker is limited to 60 W. Provisions for active thermal control are included in the galley area.

For safety and human factors reasons, several design requirements are notable. If payload assembly is required on-orbit, avoid the use of small parts that might float loose in the cabin. Containment may be required to prevent the release of gases or other substances into the cabin environment. Standard Experiment Apparatus Containers (EACs) are available for this purpose. Rounded corners and edges, hand holds, and a fire hole are other features that are incorporated when appropriate.

Investigators requiring more power and active thermal control might consider the Middeck Accommodations Rack (MAR). It can accommodate up to five standard middeck locker volume equivalents, or dedicated unique configurations sized to the MAR's capability. MAR internal volume is 16 ft^3 (0.45 m^3); its weight capability is 350 lb (160 kg). The MAR is installed in place of the middeck galley, and it provides utilities, including up to 500 W of power and 1 kW of water-loop heat rejection.

Spacelab Middeck Experiment (SMIDEX) Rack

The Spacelab Middeck Experiment (SMIDEX) Rack concept was developed to fly middeck-type experiments in Spacelab double and single racks thereby adding flight opportunities and freeing middeck locker space. The concept offers equivalent mechanical, electrical, and thermal interfaces as the Orbiter middeck.

Mounting plates are incorporated into the racks to accommodate a variety of middeck compatible experiment systems such as those using lockers, Experiment Apparatus Containers (EACs), or unique configurations. Generic cables provide up to three dc sources and one ac source from the Spacelab Experiment Power Switching Panel (EPSP) to those SMIDEX items requiring power. The cables are sized to carry 3 amps ac and 7 amps dc and are installed and routed in the Spacelab rack. Considerable additional resources can be made available from Spacelab systems where required. Power may not be available during ascent and descent phases. The cabin air loop is used for heat rejection.

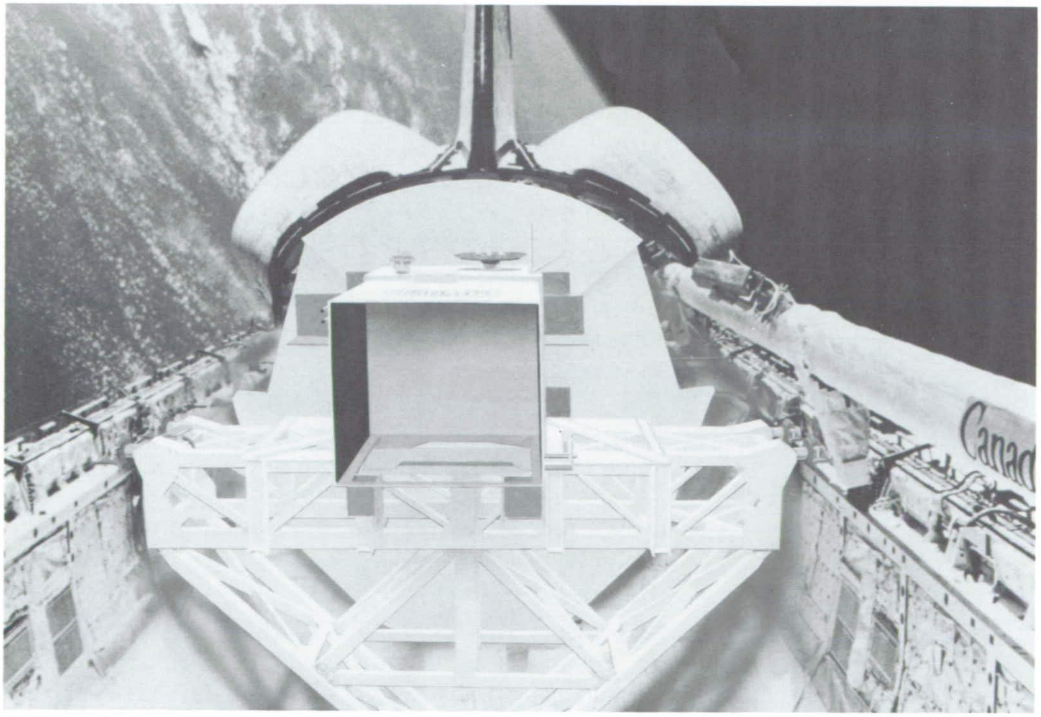
▸Retrievable Free-Flyers

The Orbiter's capability to release objects in space and recover them either on the same flight or on a subsequent flight has resulted in the retrievable free-flyer concept. First demonstrated with the German SPAS-01 payload, this capability is being used by NASA's Spartan and Long Duration Exposure Facility (LDEF) payload programs.

Retrievable free-flyers offer several advantages to the investigator. They are unaffected by disturbances and contamination resulting from Orbiter and payload activities. They can conduct viewing programs independent of the pointing requirements of other payload elements. The separation distance may be useful in coordinated measurement programs with instruments left on board the Orbiter. Finally, they may remain in orbit for extended periods of time. On the other hand, instrument operational resources are generally very limited.

Spartan

Spartan is a free-flying carrier developed by GSFC to accommodate instruments from the pointed sounding rocket program. The Spartan system itself borrows heavily from equipment developed for other programs to minimize costs.



The Spartan rides into orbit on a bridge structure before being released to conduct its observing program.

Retrievable Free-Flyers

	SPARTAN	LDEF
Structure	Spartan Service Module	80 trays: 50 x 38 x 3, 6, or 12 in. (1.27 x 0.965 x 0.076, 0.152, or 0.305 m) deep
Subsystems	Batteries Tape recorder	None
Capability		
Load	TBD	200 lb (90.7 kg)
Power	Batteries (28 kWh at 28 Vdc)	User provided
Heat Rejection	Thermal control at ± 25°C	Passive
Data Handling	Tape recorder (5 x 10^8 bits)	User provided
Control	Preprogrammed	None
Pointing	3 arc min stellar, 10 to 20 arc sec solar	Gravity gradient
Flight Frequency	1 per year	TBD
Additional Information	HQ/ES GSFC/740.1	HQ/RX LaRC
Availability	Now	Now

The Spartan Flight Support Structure on which the free-flyer rides into orbit is a modified Multi-Purpose Experiment Support Structure; the Attitude Control System (ACS) was developed for astronomical sounding rocket experiments; and the Spartan activation and checkout procedure utilizes a GAS autonomous payload controller.

The Spartan service module supports instrument operation while in the free-flyer mode. It contains ACS electronics, batteries, tape recorder, and other key elements of the system and can support remote operations for up to 40 hours. For the most part, the capabilities provided for Spartan are very similar to those provided for pointed sounding rockets. Although sounding rocket instruments are obvious candidates for Spartan, the concept allows for a great deal of flexibility in shapes and sizes. The constraint is that the entire Spartan must fit within the static envelope of the payload bay. The maximum clearance is 56 in. (142 cm) at the center of the support bridge and decreases as the Orbiter payload envelope curves to meet the bridge trunnions.

Once on orbit, a crewmember activates and checks out the Spartan. The Orbiter Remote Manipulator System then grapples the Spartan, orients it in the appropriate position, and releases it. The attitude control system is activated, the Shuttle moves away, and Spartan starts its sun and star acquisition sequence. It is then ready to follow its preloaded pointing and operation sequence. There is no radio link with Spartan, so all maneuvers are pre-programmed. About 2 hours before scheduled recapture, the Spartan is rotated to the capture orientation, and the equipment is powered down to a keep-alive status.

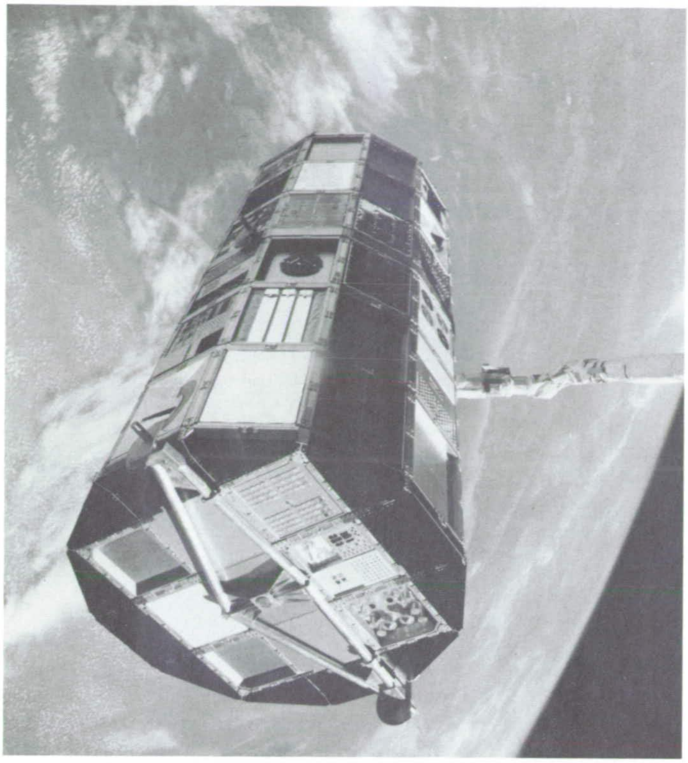
Cold gas is used to accomplish rotation maneuvers; Spartan had no capability to perform translational maneuvers.

GSFC is examining a number of ways to enhance the capability of Spartan. These enhancements will be phased with successive Spartan flights in response to user requirements. An improved valve controller to reduce jitter from 10 arc sec peak-to-peak to 1 arc sec peak-to-peak is in development. Additional near-term enhancements include improved attitude sensors to achieve better accuracy (near-term sun sensors, gyros, tracking), increased payload capability, multiple payloads capability, increased data rates, and increased power capability. Candidate future enhancements include solar panels, a momentum exchange system, and the possibility of man-in-the-loop and radio uplink and downlink capability.

Long Duration Exposure Facility (LDEF)

The Long Duration Exposure Facility (LDEF) is designed to carry large panels or trays of materials for exposure to the space environment. It coasts in orbit unpowered in a gravity stabilized attitude, and at the end of a mission (nominally 1 to 2 years), it is retrieved for return to Earth. The old panels are replaced and LDEF is placed in orbit once again.

The LDEF structure is a 12-sided cylindrical frame 14 ft (4.27 m) in diameter by 30 ft (9.15 m) in length. Trays for equipment and sample mounting are available in 3, 6, and 12-in. (7.6, 15.2, 30.5 cm) depths. Equipment and samples must not protrude beyond the plane of the cylinder face because of the close fit in the Orbiter payload bay.



The Long Duration Exposure Facility (LDEF) is positioned by the RMS for release in orbit.

Investigators must provide for their own power and data-handling needs. To assist investigators in these areas, the LDEF Project Office developed an experiment data and power system unit. The power supply module batteries can deliver 10 to 30 A-h at 28 Vdc. Modules can be ganged for additional capacity. The data system can digitize 64 analog inputs and provides a crystal-controlled clock timing signal. Data storage is provided by an incremental cassette tape recorder with a storage capacity of 14.5 Mbits.

LDEF is well-suited for studying the durability of materials in the space environment for future satellites and Space Station Freedom. It is also a good vehicle on which to fly passive experiments in cosmic ray astronomy. Contact the LDEF Project Office at the Langley Research Center for information on future flight opportunities. ■

Notes:

Notes:

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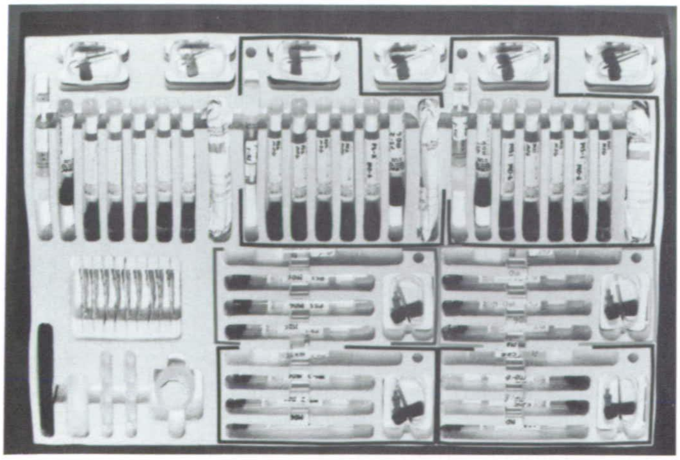
Instrument Development

Documents Describing Existing Experiment and Support Equipment

- ***Life Sciences Flight Experiments Program, Life Sciences Laboratory Equipment (LSLE) Descriptions, JSC-16254-I, September 1986***
- ***Accessing Space, A Catalogue of Process, Equipment and Resources for Commercial Users, September 1988, NASA/OCP (Code CC)***
- ***Microgravity Science and Applications, Apparatus and Facilities, January 1989, NASA/OSSA (Code EN)***



Life sciences experiments often use items such as this blood collection kit from NASA's inventory of available flight hardware.

A MAJOR CHALLENGE in developing experiment flight hardware is to configure the basic science apparatus to satisfy payload carrier requirements for interface compatibility and STS requirements for payload system safety. You must also ensure that your instrument survives the stress of launch and performs as planned in the on-orbit environment. Accomplishing these objectives demands a special knowledge of the pertinent interfaces, design requirements, and environments, and of the design approaches that work with them. The instrument developer must also know acceptable methods for verifying that the design requirements have been met at project completion. For this reason, instrument development is often a team effort: the investigator works closely with a small group of engineers and technicians who are experienced in flight hardware development. In this way, you can concentrate on details of the science to be accomplished and rely on other members of the team to handle details of design, fabrication, testing, and flight qualification.

Of course, not every experiment requires new hardware development. NASA has a growing inventory of existing flight hardware available for use by investigators. In this case, you work with the owner organization much like you would work with a development team to establish the suitability of the equipment, to modify the equipment as necessary, and to define the operation scenario.

This section and the ones that follow provide a generic discussion of STS experiment development and integration considerations as they apply throughout NASA. However, it should be recognized that some differences in terminology or approach may exist among the various NASA field centers.

Flight Hardware Life Cycle:

- *Concept definition*
- *Design and fabrication*
- *Functional and qualification testing*
- *Delivery shipping*
- *Payload integration*
- *Cargo integration*
- *Launch*
- *Flight operations*
- *Reentry and landing*
- *Cargo and payload deintegration*
- *Return shipping*
- *Storage refurbishment*

Typical Equipment Complement

- *Instrument Flight Unit - hardware and software*
- *Mechanical Ground Support Equipment (GSE) - assembly and integration aids, handling fixtures, transportation packaging*
- *Experiment Checkout Equipment (ECE) - test inputs, controls, and monitor equipment for functional testing and interface verification*
- *Electrical Ground Support Equipment - operations console for real-time data capture, reduction, and display*
- *Stowage Equipment - samples, film, spares, etc.*
- *Test Articles - mounting fixtures (modal survey), test parts, qualification unit, etc.*

Typical Experiment Project Documentation:

- *Project plan*
- *Progress reports*
- *Design and Performance Specification (D&PS)*
- *Experiment Requirements Document (ERD)*
- *Drawings, schematics, materials lists, and mass properties data*
- *Verification plan*
- *Verification analyses and test results*
- *Structural models*
- *Thermal data*
- *Safety compliance data*

►The Elements of an Experiment System

The instrument flight unit is merely one element of a complement of equipment and documentation developed during the course of an experiment project. Other flight equipment may include stowage items such as samples, film, and spare parts. Special ground support equipment often is required and may include checkout equipment for functional testing prior to payload integration and for interface verification tests during payload integration. An operations console may be needed during the flight for real-time data display, capture, and analysis. Finally, the instrument may be large enough to require special handling fixtures. Thus, instrument development really means instrument system development.

Documentation requirements for NASA-sponsored investigations are established by the experiment project office to which the investigation is assigned and by the mission management office responsible for the instrument's flight. The documentation set meets the needs of the project office for management data as well as the needs of the mission office for integration data. The latter includes information on instrument characteristics and operations requirements as well as evidence of design verification and safety compliance.

NASA project management practices are fairly standard. A number of formal reviews are held during the instrument development process; these typically include a Preliminary Requirements Review (PRR), a Preliminary and a Critical Design Review (PDR and CDR), and an Acceptance Review (AR)/Integration Readiness Review (IRR). The technical design is controlled by a Design and Performance Specification that should contain all the requirements to which the design must respond.

►Developing the Flight Hardware Concept

The first decision to be made in developing the flight hardware concept is the selection of a suitable accommodation mode. This decision may be driven by operational considerations such as viewing, resource, crew interaction, and access requirements. It may also be driven by programmatic considerations such as flight opportunity, flight cost, and integration schedule. The accommodation mode establishes the interfaces, environments, and to some degree, the design requirements that must be reflected in the concept. However, you are often left with important choices that affect your use of STS and carrier capabilities.

User instruments and Orbiter operations must share the full spectrum of available resources, which range from mounting and stowage space to crew time and attention. While a substantial level of resources is available to meet essential needs, the motto that applies to the discretionary use of resources is "less is better." Thus, you are encouraged to distinguish between real experiment requirements and "wants" and to use prudence when establishing the resource utilization characteristics of your experiment. Resource demands and other operational requirements do impact operational autonomy, allocated operating times, and manifesting opportunity.

Of particular importance early in concept definition is the

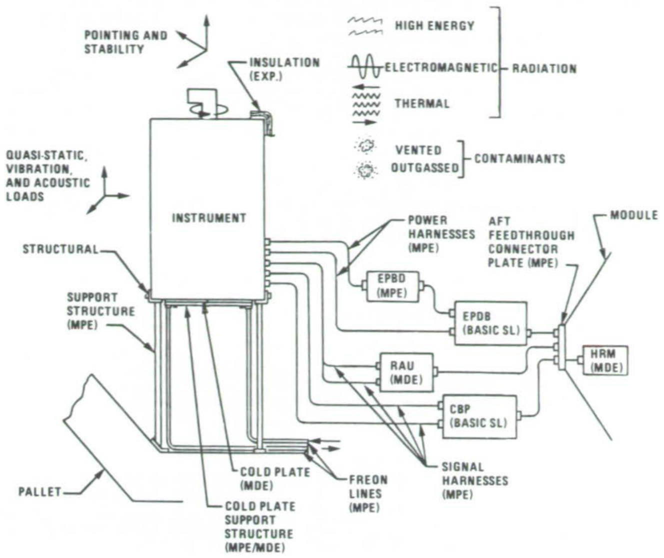
selection of the instrument control mode. From an operational standpoint, automation with provision for crew or uplink intervention is preferred. It enables the experiment to proceed independently of crew or uplink availability yet provides for event-driven operation or setpoint adjustment.

Likewise, the use of the flight crew can significantly affect your instrument concept. The flight crew has played a vital role in the setup, operation, and troubleshooting of many experiments. Valuable lessons have been learned about the design of crew interfaces, appropriate uses of crew time, and crew work capabilities in zero-g. The Science Support Group of the Astronaut Office at JSC welcomes inquiries from investigators and can assist in defining a suitable crew role relative to your experiment objectives.

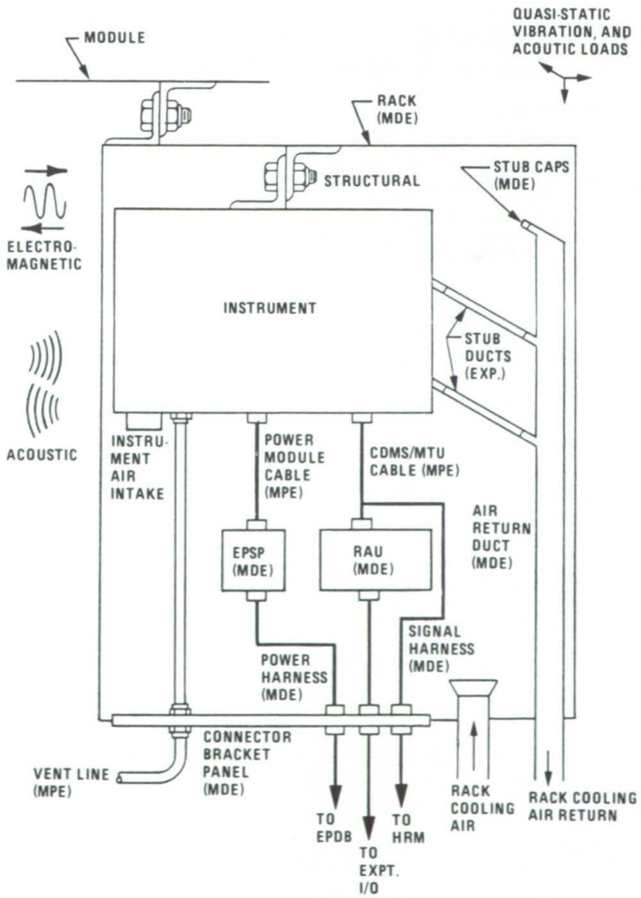
The monitoring function provides a basis for assessing instrument health and experiment progress and may be performed either on board or on the ground. In most cases, monitoring is accomplished through carrier and Orbiter data channels. During the payload integration process, a great deal of effort is invested in developing software modules for handling and displaying monitored data. You are advised to limit the monitored data set to items essential for real-time control. Extra indicators increase hardware and software complexity, impact testing requirements, compete for telemetry capacity, and provide additional points for failure.

Data management is another functional area of major importance. If film or experiment samples are involved, you must arrange for suitable stowage. When the data are encoded into digital, analog, or video form, several options are available that involve telemetry, onboard recording, or a combination of the two. In most cases, downlinking data is the primary option. While it forces you to compete for telemetry resources, it does offer the opportunity to review the raw data in real or near-real time. In other cases, onboard recording of data may be preferable. Carrier or STS-provided recorders generally offer very limited capability with the exception of video. Recording data within the instrument can reduce the number of interfaces and the potential for operational conflicts but entails the expense of developing a flight-qualified data storage system.

Many investigations need access to the Orbiter as close to launch as possible to load samples, film, and specimens and for final servicing, testing, and checkout. It is important that the experiment flight equipment be designed to facilitate these tasks. Special procedures have been developed on previous missions for performing time-critical servicing, such as cryogen top-off and live specimen loading on the launch pad. Two instruments on Spacelab 2 used liquid helium in its superfluid state, and vacuum pumps for maintaining the superfluid state were built into the flight equipment. Cryogen top-off was accomplished on the pad 4 to 5 days before launch, and the pumps were operated continuously using ground power until shortly before launch. Research animals were used on Spacelab 3, and the loading of animals into their habitats in the module was accomplished about 18 hours before launch. More commonly, time-critical items are loaded into the



Typical Pallet-Mounted Instrument Interfaces



Typical Rack-Mounted Instrument Interfaces

Normal Instrument Access Opportunities for PIs:

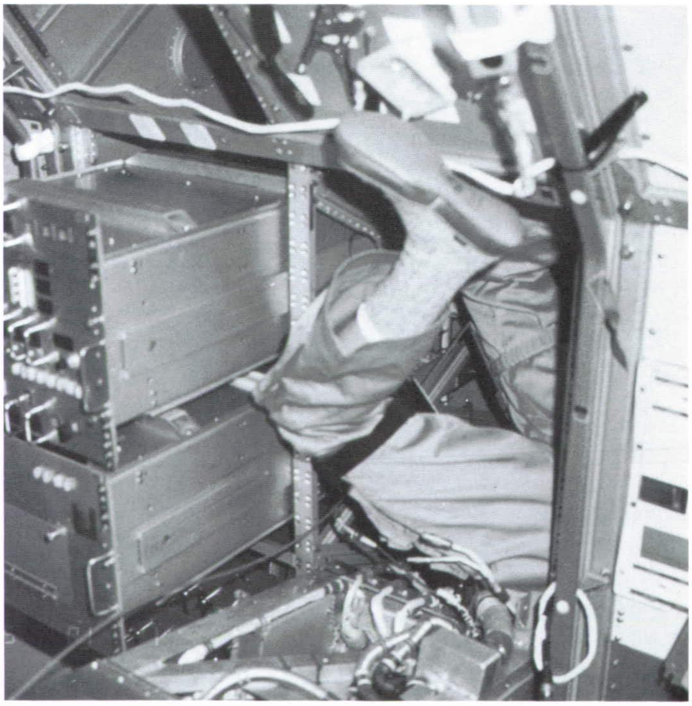
ACCOMMODATIONS	LAST ACCESS BEFORE LAUNCH (months)	FIRST ACCESS AFTER LANDING (weeks)
Spacelab Modules	2 to 3*	3 to 4*
Spacelab Pallet	2 to 3	3 to 4
Middeck	3 to 8 days*	1 day*
MPESS A/B	2 to 3	3
GAS Cans	2 to 3	2
Hitchhiker	2	2 to 3
SPARTAN	1	1

Time can be reduced with justification to install/remove time-critical samples.

Late/Early Access Possibilities for Time-Critical Servicing:

ACTIVITY	TIME (hr)*
Pre-Launch:	
Final Servicing in Payload Bay	50-60
Spacelab Module Late Access for Specimen Loading	24-30
Middeck Late Loading	12-18
Post Landing:	
Middeck Early Offloading	2
Spacelab Module Early Access for Specimen Removal	4-5

Requires justification



The flight crew can play a vital role in correcting problems. Here a Spacelab 3 crewmember repairs an instrument which he helped design.

middeck in the late stages of the countdown and transferred into the module on orbit. Likewise, time-critical items may be transferred to the middeck from the module at the end of the mission for rapid off-loading after landing.

Finally, the ability to troubleshoot and solve problems during the mission can mean the difference between experiment success and failure. It is not uncommon for experiment hardware to malfunction; experience has proven that the flight crew with ground support can play a vital role in diagnosing problems and implementing solutions. However, the hardware design must include the necessary features to make this possible. Front panel indicators are important when telemetry is restricted; access and flight spares are required when repairs are possible.

▶Design Guidelines and Requirements

STS management has established an extensive set of design requirements to ensure that user-provided equipment is safe and can be operated without interfering with either the Orbiter or other instruments. An additional set of requirements governing instrument-to-carrier interfaces is imposed by carrier program management (Spacelab, Spartan, Hitchhiker, etc.). While these requirements affect many aspects of instrument design, it should be emphasized that they are intended only to ensure compatibility and safety. Design considerations that ensure successful performance and operation on orbit are the responsibility of the instrument developer.

Top-level design requirements are summarized here to identify general design considerations that receive close attention before flight certification is granted. For reference purposes, a general list of requirements documents is also presented. Once an investigation is assigned to a mission, the instrument developer works closely with the mission manager to identify the specific set of requirements to be met by the instrument for certification. In some cases, certification requirements are coordinated directly with the STS payload integration manager. For example, commercial experiments in the Orbiter middeck are handled this way.

Safety

Safety has always been a primary concern in the manned space program, and NASA has established a comprehensive program of analysis, documentation, and review activities to ensure payload ground and flight safety. This program covers both equipment and operations. Safety policy and basic safety requirements for all payloads using the STS are presented in NSTS 1700.7B which is the revised version of NHB 1700.7A. Safety aspects of ground support equipment design and ground operations are governed by KHB 1700.7. Several other documents, both generic and carrier-specific, have been developed to interpret these policies and requirements and define approaches for safety compliance.

In developing an experiment concept the investigator should be aware of conditions that NASA considers hazardous; such conditions must be eliminated or adequately controlled. A hazard is defined as the presence of a potential risk

situation caused by an unsafe act or condition. Hazards are classified as critical or catastrophic. A critical hazard can result in damage to STS equipment, a nondisabling personnel injury, or the use of unscheduled safing procedures that affect operations of the Orbiter or another payload. A catastrophic hazard can result in the potential for a disabling or fatal personnel injury or in the loss of the Orbiter, ground facilities, or STS equipment. Hazards must be eliminated or controlled either to an appropriate level of failure tolerance or by compliance with specific requirements other than failure tolerance. In general, design aspects associated with critical hazards must tolerate a single-point failure or operator error without occurrence of the hazardous event while those associated with catastrophic hazards must be two-fault tolerant. Ensuring inherent safety through the selection of appropriate features is a major design goal, and damage control, containment, and isolation of potential hazards should be included in design considerations. Safety devices, warning devices, and special procedures are other hazard reduction measures.

Verification

Verification is the process through which the instrument developer demonstrates and documents that experiment equipment meets each applicable interface and safety requirement. This is accomplished through a combination of testing, analyses, and inspection. Verification covers both ground and flight hardware, and the verification program must be completed successfully before hardware acceptance for integration and flight. For this reason, the review of verification requirements pertaining to your flight situation is a recommended starting point for embarking on experiment system design.

For each payload program, a set of generic verification requirements has been developed that is tailored to the specific STS carrier. These requirements encompass both compatibility and safety aspects of the design. Each requirement is defined by an identification number, description of the requirement, verification method (test, analysis, or inspection), and requirement source. More than one verification method may be specified. The mission manager will assist you in determining which of the generic requirements are applicable to your design and flight situation and how they will be met. In many cases the instrument developer is required to develop a formal verification plan complete with a schedule for each analysis and test. Analysis results and test data are then submitted to satisfy the requirements. Upon completion of the verification program the flight equipment becomes certified as ready for ground and flight use.

Structural Integrity

In most cases, structural/mechanical design presents the biggest engineering challenge of the instrument development process. First of all, the instrument developer must establish and maintain an effective structural analysis, structural test, and structural assessment program (using approved procedures) to assess and verify the structural integrity of all flight equipment. This ensures against such events as structural

Payload Safety Documents

NSTS 1700.7:	*Safety Policy and Requirements for Payloads Using the Space Transportation System (STS)*
KHB 1700.7:	*STS Payload Ground Safety Handbook*
JSC 11123:	*STS Payload Safety Guidelines Handbook*
JSC 13830:	*Implementation Procedure for STS Payloads System Safety Requirements*
JA-012:	*Spacelab Payload Project Office Payload Safety Implementation Plan*
NSTS 18798:	*Interpretations of NSTS Payload Safety Requirements*

Hazard Groups

- *Collision*
- *Contamination*
- *Corrosion*
- *Electrical shock*
- *Explosion*
- *Fire*
- *Injury and illness*
- *Loss of Orbiter entry capability*
- *Radiation*
- *Temperature extremes*

MSFC Verification Requirements Documents

JA-061	*Payload Mission Manager Interface and Safety Verification Requirements for Instruments, Facilities, MPE, and ECE on Space Transportation System (STS) Spacelab Payload Missions*
JA-081	*Payload Mission Manager Interface and Safety Verification Requirements for Instruments, Facilities, MPE, and ECE on Space Transportation System (STS) Partial Payload Missions*
JA-276	*Payload Mission Manager Interface and Safety Verification Requirements for Instruments, Facilities, MPE, and ECE on Space Transportation System (STS) Orbiter Middeck Payload Missions*

failure; the leakage of hazardous fluids; or the release of equipment, loose debris, or particles that could damage the Orbiter and payload systems or injure the crew. Second, the design must survive severe dynamic loads during launch and maintain alignment, deploy, or otherwise perform on orbit to satisfy the science requirements. In certain cases, experiment flight equipment was developed with inadequate margins of safety, unqualified weldments, and inadequate structural verification documentation. Such equipment was not accepted for integration until the applicable requirements were met.

Safety-critical structures are given special emphasis. All structural elements (including interfaces, fasteners, and welds) in the primary load path plus pressure systems, glass, and rotating/articulating machinery are safety critical and must be analyzed to show positive margins of safety. Structural items that are contained (such as GAS payloads) do not have to be analyzed for positive margins.

The loads criteria for safety-critical structures are usually given in terms of load factors pertaining to each phase of flight operations and/or load conditions. Normally, all combinations of load factors corresponding to a given flight phase must be applied to obtain limit loads for that phase. The design load factor is the largest of the combined load factors that apply during a flight. In general, the key design drivers are the quasi-static (g-level) and dynamic load factors for launch and the quasi-static load factor for landing (nominal and emergency). These design load factors vary depending upon the carrier, equipment/payload location, and type of mounting.

For design verification, detailed static and dynamic (modal) analyses must be performed with respect to the above loading conditions. For missions managed by the Marshall Space Flight Center an analytical model may be used for any component weighing less than 40 lb (18 kg) and having a minimum natural frequency greater than 35 Hz when constrained at its mounting interface. For items weighing more than 40 lb (18 kg) or with a minimum natural frequency less than 35 Hz, a finite element math model is required that includes both experiment equipment and attachment hardware. This requirement may differ somewhat for other carrier programs. Current STS procedures specify the NASA Structural Analysis (NASTRAN) computer program (COSMIC version) for model development or, in the event that COSMIC/NASTRAN is not available to the payload developer, the model provided must be convertible to COSMIC/NASTRAN by the payload integrator. The model must have enough fidelity to establish loads and load paths in all critical structures and represent system frequencies and mode shapes up to 75 Hz. The model is provided to the payload integrator together with a model description, assembly and installation drawings, sample runs with control statements, and analytical quality checks. The model is subsequently used in a verification coupled loads analysis of the entire payload system.

A fracture control program is generally required to provide assurance that no catastrophic hazards will result from the initiation or propagation of flaws, cracks, or crack-like defects in instrument structural components. All safety-critical parts are also potentially fracture critical and must go through a screening process. Those which cannot show containment or redundant load paths must be analyzed to determine the critical initial flaw size and inspected per appropriate specifications. The number of potential fracture critical items can be reduced by providing multiple load paths, containment, or restraint, or by designing for low cyclic stress. A fracture mechanics analysis must be provided for all pressure vessels and rotating machinery. The payload integrator normally performs the fracture control analysis. However, the instrument developer is responsible for identifying safety-critical structures and furnishing stress analyses, material properties, and other supporting data. Finally, welds and brazes on critical structures should be avoided wherever possible because of stringent requirements for qualification, design, test, and inspection.

Design Aspects for which Compliance is Required

Materials of fabrication:	*Flammability* *Offgassing/outgassing* *Stress corrosion* *Materials compatibility*
Welds and fasteners	
Electrical:	*Connectors* *Cable bundling* *Power distribution* *Bonding*
Signal:	*Protocols and formats* *Voltage levels and impedances*
Vibration	*X, Y, Z Axes*
Acoustics:	*Sound pressure levels at specific frequencies*
Load Limit Factors: (X, Y, Z Axes)	*Lift-Off* *Ascent* *Descent* *Landing* *Emergency landing*
Angular acceleration:	*Ascent* *Descent*
Fracture control	
Environment:	*Temperature* *Ionizing radiation* *EMC/EMI*
Human engineering	
Safety	

Materials of Construction

Materials and processes for fabricating flight hardware require careful consideration because of performance, safety, and compatibility impacts. Selection must be based on operational requirements for the particular application as well as design engineering properties of the candidate materials. Properties to be considered include strength, fatigue, thermal vacuum stability, fracture toughness, corrosion and stress corrosion behavior, flammability, and offgassing.

Materials Selection Documents

MSFC HDBK 527/JSC 09604:
Material Selection List for Space Hardware Systems

MSFC SPEC-522:
Design Criteria for Controlling Stress Corrosion Cracking

NHB 8060.1:
Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion

NSTS 22648:
Guidelines for Flammability Configuration Analysis for Spacecraft Applications

NSTS 22667:
Fracture Control Requirements for Payloads Using the Space Transportation System

During design, each instrument developer should select materials of fabrication from a materials selection list handbook such as MSFC-HDBK 527/JSC 09604. The materials in this handbook are rated for the various characteristic properties according to STS agreed-upon criteria. A Materials Usage Agreement (MUA) must be submitted by the instrument developer for all materials not rated "A", the highest rating. A mission management representative will help the instrument developer prepare this MUA. The instrument developer also prepares and submits for approval a Materials Identification and Usage List (MIUL), which describes and verifies the materials used in the design and fabrication.

This list covers the original design and subsequent changes. At a minimum, materials, parts, and components must be identified by material, trade name, usage environment, thickness, surface area, and detail drawing or part number, temper and form for metals, and specification. The list also includes all aspects of applicable usage environment, such as intermittent exposure, protective measures, coatings, finishes, offgassing, corrosion, stress corrosion, flammability, and resistance to the operational environment. If this list is started at the onset of fabrication and continued as a log during the process, it is much easier to prepare and validate. Compliance with material requirements must be proven by a verification process.

Flammability is a concern for any material used either inside or outside of the habitable areas. Payload materials must be non-flammable. When use of flammable materials cannot be avoided, then separation of these materials to prevent propagation paths and separation from possible ignition sources is required to the maximum extent possible. Minimizing the use of flammable materials is the preferred means of controlling this hazard. Materials are considered non-flammable or self-extinguishing if they meet the applicable flammability test requirements.

With regard to other requirements, non-metallic payload materials to be carried within the Orbiter cabin or Spacelab module must also meet requirements for odor and toxicity (see NHB 8060.1), and use of materials that produce toxic or odorous offgassing is to be avoided. Non-metallic materials located in non-habitable areas are required to meet the thermal vacuum stability (outgassing) requirements. Metallic parts should demonstrate a required level of resistance to stress-corrosion. Finally, a number of materials are forbidden or restricted. For Spacelab, forbidden materials include mercury, polyvinyl chloride, and carcinogenic or toxic materials. Restricted materials include shatterable or flaking materials, beryllium and berryllium alloys, cadmium, and zinc.

STS and Carrier Interface Constraints

This section presents an overview of major instrument interfacing considerations. Most detailed interface requirements for a given carrier are covered by its set of interface definition documents. The Spacelab Payload Accommodations Handbook (SPAH) serves this purpose for Spacelab. Similar handbooks are available for other carrier systems and the Orbiter middeck.

Structural and Mechanical: Structural integrity and materials requirements were presented in previous sections. In addition, mass property and center of gravity limits are imposed consistent with the load-bearing capacity of racks, pallets, or other support structures.

In Spacelab, rack-mounted equipment may protrude or deploy into the module center aisle, and nominal envelopes are defined. However, case-by-case restrictions may be applied to avoid conflicts with ground processing operations, crew habitability, and other equipment. Likewise, there are strict limits to instrument extensions in the payload-bay, and jettisoning provisions are required for deployed equipment in the event of a restow failure.

Electrical: Electrical power and networks requirements are specified for the integrated payload. These include aspects such as permissible wire size, fusing and protection, bonding, grounding, isolation, cable harnessing, and cable connectors.

Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) properties of the radiated and conducted emissions from the instrument must be approved by the mission manager.

Command and Data Management/Software: Instrument Command and Data Management System (CDMS) interfaces must comply with carrier or Orbiter requirements. Software must be compatible with either the Experiment Computer Operating System (ECOS) or the Experiment Computer Applications Software (ECAS) for Spacelab payloads and with Orbiter General Purpose Computer (GPC) software requirements for payloads using its support. Functional verification of the CDMS/software interfaces must be completed prior to acceptance for integration with the carrier. For Spacelab this can be performed using the Payload Development Support System (PDSS)/Spacelab Experiment Interface Device (SEID), which simulates the experiment computer and Remote Acquisition Unit (RAU) interfaces.

Instrument Cooling Options

INSTRUMENT LOCATION	COOLING OPTIONS
Orbiter Flight Deck	• Convective and radiation cooling of rack face by cabin environment • Convective cooling of the rack by drawing cabin air through the rack
Spacelab Module	• Convective cooling of rack face by cabin air • Convective cooling of the rack by Spacelab avionics air flow • Liquid cooling by interfacing with the experiment heat exchanger • Liquid cooling by interfacing with experiment cold plates
Payload Bay Carrier	• Passive cooling by use of insulation blankets, thermal isolators, surface coatings, and heat pipes • Active cooling by interfacing with the Orbiter payload heat exchanger directly or via experiment cold plates

Thermal/Environment Control System (ECS): Thermal constraints that the instrument developer should consider during design are determined by the STS carrier selected to accommodate the instrument and the type of environmental control chosen. These options are dependent upon the type of cooling required (i.e., cold plate, heat exchanger, avionics, or cabin air, etc.), the allowable temperature range for the instrument, and the location of the instrument in the Shuttle.

The detailed thermal design and analysis of experiment hardware are the responsibility of the instrument developer. The instrument developer establishes heater power requirements, energy requirements, temperature gradient control techniques, and the details of the thermal design necessary to meet the instrument performance requirements. Heaters, radiators, thermal-optical coatings, insulation, isolators, heat sinks, etc., are incorporated to implement the thermal design.

If you are planning a reflight mission, it is recommended that STS hot and cold design environments be used as thermal limits for thermal design of payload bay-located instruments. This provides a more hostile environment than the actual mission flown but allows reflight with little or no thermal redesign. The integration contractor normally provides both hot and cold recommended design conditions for a given mission as well as a nominal environment. Realistic thermal environments can be provided only if the total integrated mission configuration is analyzed for reflections from all surfaces in the cargo bay.

If the instrument is to be located in the Spacelab module, the thermal design job generally is simpler. The instrument developer can use convective cabin air or avionics rack cooling, the rack heat exchanger or cold plate, or instrument unique heat exchangers.

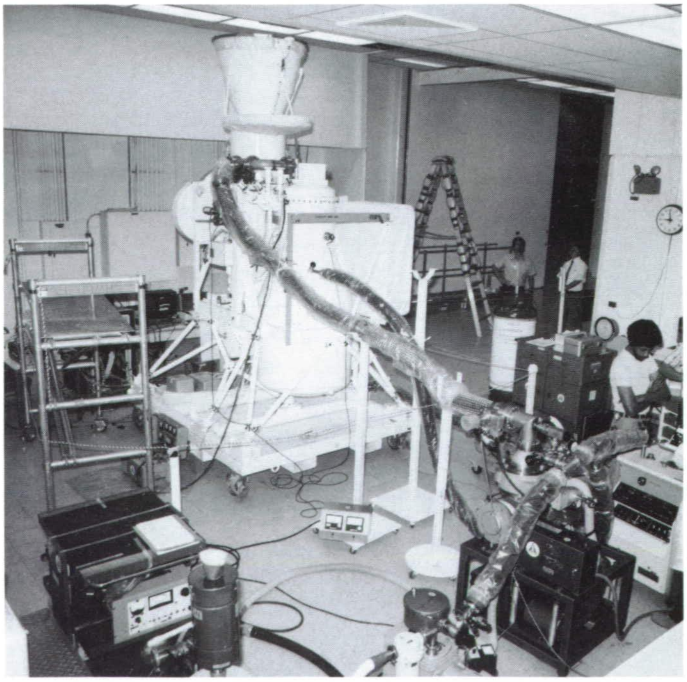
Rack-mounted experiments should be thermally designed by the Aeronautical Radio, Inc. (ARINC) method (ARINC Specification 404A, Air Transport Equipment Cases and Racking). This requires maximum unit pressure drop limits and the distributed heat load to be accounted for in the air duct designs.

Experiment equipment cooled by cold plates requires careful mechanical attachment. Some of the factors affecting this interface include bolting pattern, number of bolts used, bolt torque, type and thickness of interface filler material, and roughness/flatness of mating surfaces.

The temperature extremes of the Spacelab module or the Orbiter middeck area during the interval from prelaunch, launch to reentry, and post-landing may impose some restrictions on life sciences experiments. Limited power available during these mission phases also limits the performance possible from supplemental mission-peculiar equipment or experiment unique environmental control systems which can be used to offset these possible temperature extremes.

▸Ground Support Equipment (GSE)

Experiment Checkout Equipment (ECE) normally is required to support the experiment instrument operation, test, checkout, installation, and integration into the STS carrier. The design and supply of such equipment is the responsibility of the instrument developer. The equipment remains the property of



Ground support equipment plays an important role in the functional test and checkout of flight hardware. The investigator is responsible for arranging for GSE.

the instrument developer and is returned along with the experiment equipment at the end of the flight.

Normal operations at the Kennedy Space Center (KSC) provide for the experiment teams to work with their flight hardware prior to integration. Some operations, especially troubleshooting, require use of ECE. General purpose test equipment, such as voltmeters, power supplies, and oscilloscopes, are available at KSC, but the investigator is cautioned against depending on KSC equipment because it is not always available. Specialty or unique checkout equipment must be supplied by the instrument developer.

For missions managed by Marshall Space Flight Center, a discussion of ECE design requirements can be found in document JA-077, Experiment Checkout Equipment (ECE), General Design Requirements. These requirements are applicable to all ground support equipment provided by an experiment or facility developer for use either at KSC or at the ground control center. They are the minimum standards that the checkout equipment must meet for safety of personnel and compatibility with other flight/ground hardware.

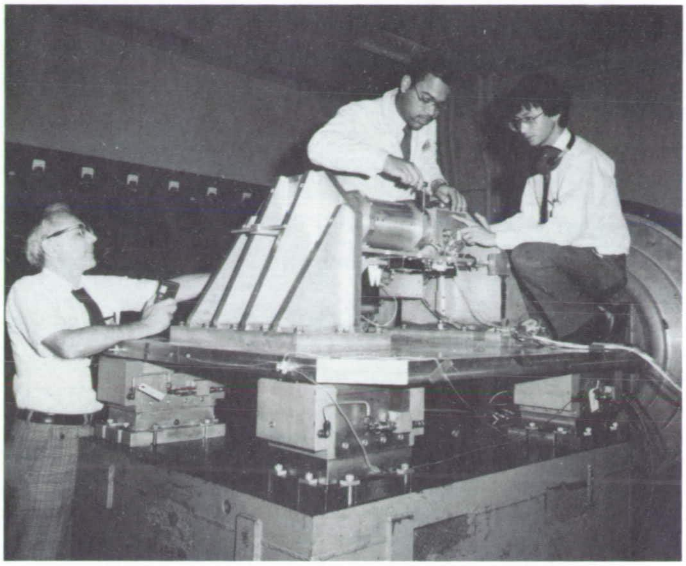
Ground Support Equipment (GSE) for handling that is unique to the experiment must also be provided by the instrument developer, e.g., a special sling for attaching to, lifting, and rotating the experiment equipment. Hoisting, lifting, and transporting facilities, on the other hand, are available at KSC; however, the instrument developer must identify and submit requirements for using the equipment.

▶Testing for Success

The instrument developer is required to perform a number of tests on the flight hardware in accordance with the verification plan generated for the instrument development project. Foremost among required tests is the verification of structural dynamics math models where such a model must be submitted. This is generally accomplished with a modal survey test, although sine sweep vibration and impact tests may be acceptable depending on carrier program requirements. A modal survey is performed with the instrument in its standard mounting configuration and normally requires development of a test fixture to simulate the flight mounting structure.

The modal survey test must be instrumented in a manner to verify all natural frequencies and mode shapes below 75 Hz. The test article is gently driven with a random or white noise excitation, and the response is characterized by amplitude and phase data taken at selected points on the structure. The pretest analytical results must be correlated with the modal survey test results within ±3 percent for the fundamental frequency in each axis and within ±8 percent for higher order frequencies.

It is the instrument developer's option to perform other structural tests involving piece parts, a protoflight unit, or a separate qualification unit. Testing is the preferred way to prove that a piece of structure is flight worthy, and it generally allows lower factors of safety to be used in the design.



Flight hardware assemblies and components undergo a number of tests to receive certification and ensure performance. Here, a GAS payload is being readied for a vibration test.

For equipment installed in habitable areas, a toxic offgassing test is either required or may be performed in lieu of an offgassing analysis. This is an assembly or "black box" level test. Equipment items are subjected to an elevated temperature in a closed environment for a specified duration and the resultant offgassed constituents are analyzed.

Other tests or measurements that may be required for verification include the following: weight, center of gravity, Electromagnetic Interference (EMI) emissions, cable continuity, avionics flow and coolant loop pressure drops, coolant loop leakage, thermal vacuum stability, and data system interfaces. Again, the mandated verification tests are for flight certification only. You may elect to perform any number of additional tests to ensure that your flight hardware performs in space as planned after exposure to the launch and the on-orbit environment.

NASA has developed and maintains many first-rate test facilities at its field centers and generally makes them available to support experiment system testing and qualification. Check with your mission manager about making arrangements for their use. Commercial users might negotiate for test facility time in their agreements with NASA. ■

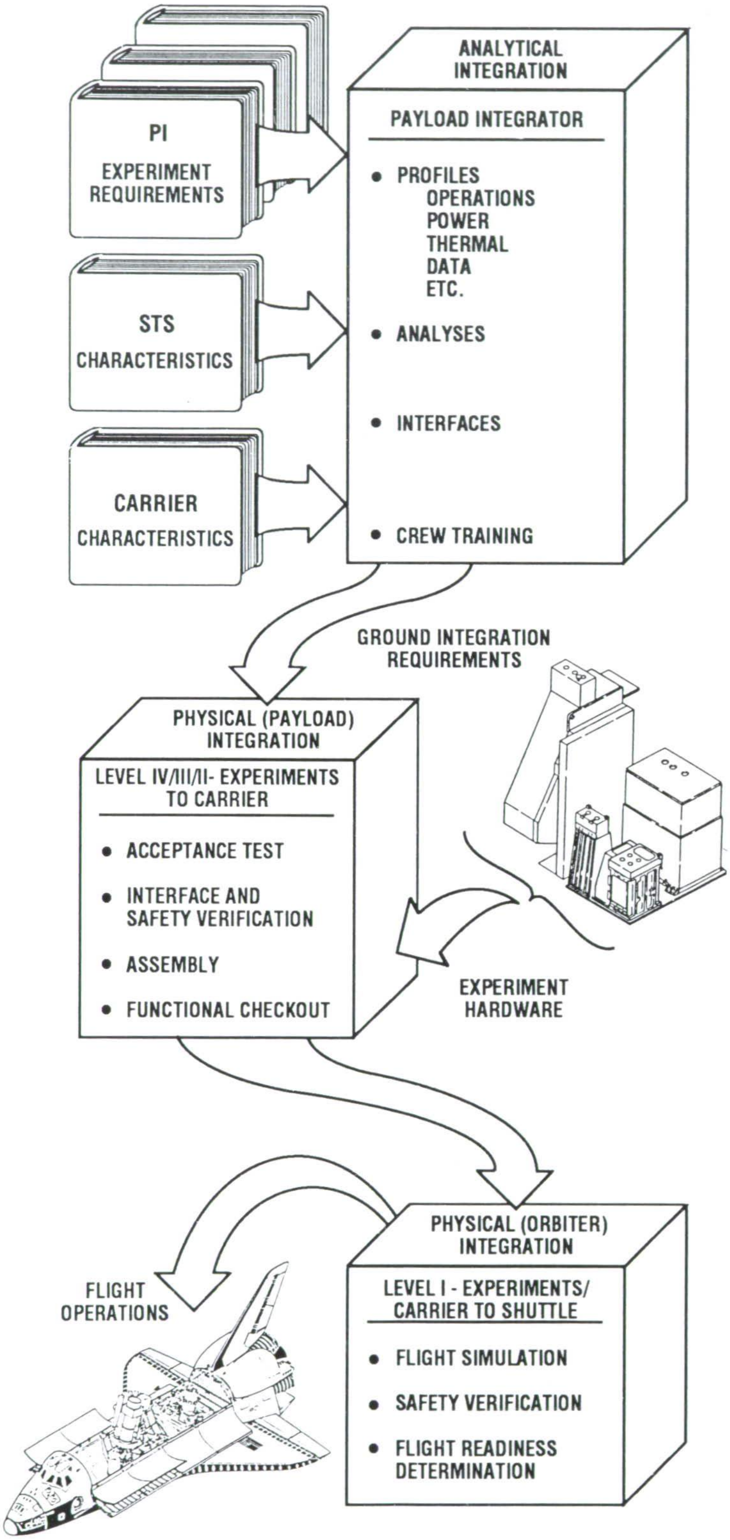
Notes:

6
Payload Integration

THE PRIMARY GOAL of the payload integration process is to assemble a complement of user instruments on a carrier in a way that maximizes the scientific return of the mission while effectively utilizing the physical and functional resources of the Shuttle. Payload integration is accomplished in two major phases: the analytical integration phase is the planning and preparation, including payload design, analysis, and development of mission-peculiar hardware; the physical integration phase is the assembly and checkout of experiment and carrier hardware.

During the early phases of the integration process, the Principal Investigator, working in concert with the developer or owner of the experiment equipment, is responsible for providing the Payload Mission Manager with a complete description of the experiment equipment and its physical and functional interface requirements. Later on, investigators participate in payload integration reviews and help evaluate the emerging accommodation design and operations plan with respect to their requirements. Finally, investigators are required to participate in the payload test and checkout activities during physical integration.

The discussion that follows uses Spacelab as an example, since it has the most comprehensive set of documentation and activity requirements. Other carrier programs such as Get Away Special (GAS), Hitchhiker, and Spartan involve subsets of these documentation and activity requirements commensurate with reduced payload and mission complexity.



Payload Integration Flow

▶The Analytical Integration Process

Under most circumstances a mission manager orchestrates the integration process and is ultimately responsible for definition and design of the integrated payload, for verification of STS compatibility and safety compliance, and for coordinating requirements with STS management and the managers of supporting organizations. To fulfill these responsibilities during analytical integration, the mission manager relies on a team of integration specialists. Members of this team will work with you during the analytical integration process to coordinate the details of integrated payload and mission design.

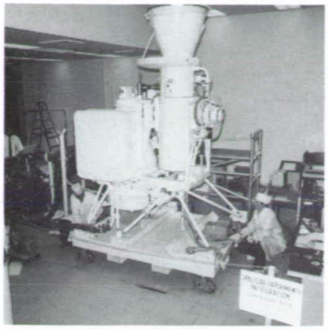
Using your experiment requirements and instrument characteristics as inputs, the integration team develops a preliminary payload concept. Engineering analyses are performed to validate the payload concept, formal interface and operation agreements are negotiated with the investigators, and unique interfacing hardware and software are developed as required. Ground integration requirements are cataloged to guide preparations for physical integration. The experiment safety compliance data are reviewed and certified, and payload safety issues are coordinated with JSC (flight) and KSC (ground) safety review panels. Data processing requirements are identified and coordinated with GSFC (science data) and JSC (video services, trajectory history, and Orbiter ancillary data).

The integration team also develops inputs to the STS Payload Integration Plan (PIP). The PIP is the technical contract between the mission manager and STS management. A set of PIP annexes supply data needed by STS management to reconfigure Shuttle flight and ground systems so that the services requested for the mission are provided. Finally, the integration team develops detailed structural dynamics and thermal math models for STS loads and thermal verification analyses using your inputs. Flight operations planning and preparation are very much a part of the integration process and are covered in the next chapter.

Key Documentation

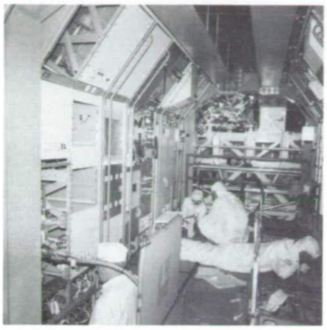
The information flow between you and the analytical integration team is a critical aspect of the payload integration process. To facilitate payload interface definition and operations planning, all payload projects require you to submit a requirements document early in the integration cycle; this document describes experiment equipment characteristics, interfaces, and operational requirements. The content and format may vary depending on the payload program. For MSFC Spacelab payloads, this document is called an Experiment Requirements Document (ERD). GAS users submit a Payload Accommodation Requirements (PAR) document; Hitchhiker users submit a Customer Payload Requirements (CPR) document.

For life sciences missions managed by JSC, discipline project offices (called Payload Project Offices) play an intermediary role by coordinating and consolidating mission science. Each discipline office submits an Integrated Experiment Requirements Document (IERD) to JSC mission management covering the entire group of experiments being developed under discipline office cognizance.

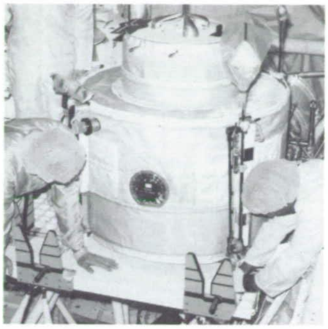


Instrument Testing

Spacelab Module Integration



Rack/Module Integration



Instruments Mounted to Pallet

PRINCIPAL INVESTIGATORS (PI)

- EXPERIMENT
  - DEFINITION
  - REQUIREMENTS
  - DATA OR OTHER PRODUCTS
- SCIENTIFIC REPORT

EXPERIMENT PAYLOAD ELEMENT DEVELOPERS (EPED)

- DESIGN, DEVELOPMENT, DELIVERY OF INSTRUMENTS OR EXPERIMENT FACILITIES HARDWARE AND SOFTWARE
- INTEGRATION/OPERATIONS SUPPORT FOR EQUIPMENT HARDWARE/SOFTWARE

PAYLOAD MISSION MANAGER (PMM)

- INTEGRATED PAYLOAD DEFINITION
- PAYLOAD ELEMENT PHYSICAL INTEGRATION
- INTEGRATED PAYLOAD ELEMENT COMPATIBILITY AND SAFETY
- INTEGRATED PAYLOAD FLIGHT PLANNING AND OPERATIONS
- INTEGRATION INTERFACE MANAGEMENT

MISSION PECULIAR EQUIPMENT (MPE) PAYLOAD ELEMENT DEVELOPERS

PAYLOAD ELEMENT UNIQUE INTERFACING HARDWARE/ SOFTWARE
- CABLES
- STRUCTURES
- BRACKETS, ETC.
- CONTROL EQUIPMENT/ SOFTWARE
- ETC.

GROUND DATA PROCESSING FACILITY MANAGER

- SPACELAB DATA PROCESSING FACILITY
- HUNTSVILLE OPERATIONS SUPPORT CENTER
- PAYLOAD OPERATIONS CONTROL CENTER

HOST CARRIER PROGRAM MANAGER

- PAYLOAD-TO-CARRIER INTERFACE COMPATIBILITY
- FUNCTIONAL CHECKOUT
- FLIGHT ANOMALY RESOLUTION
- FLIGHT READINESS VERIFICATION

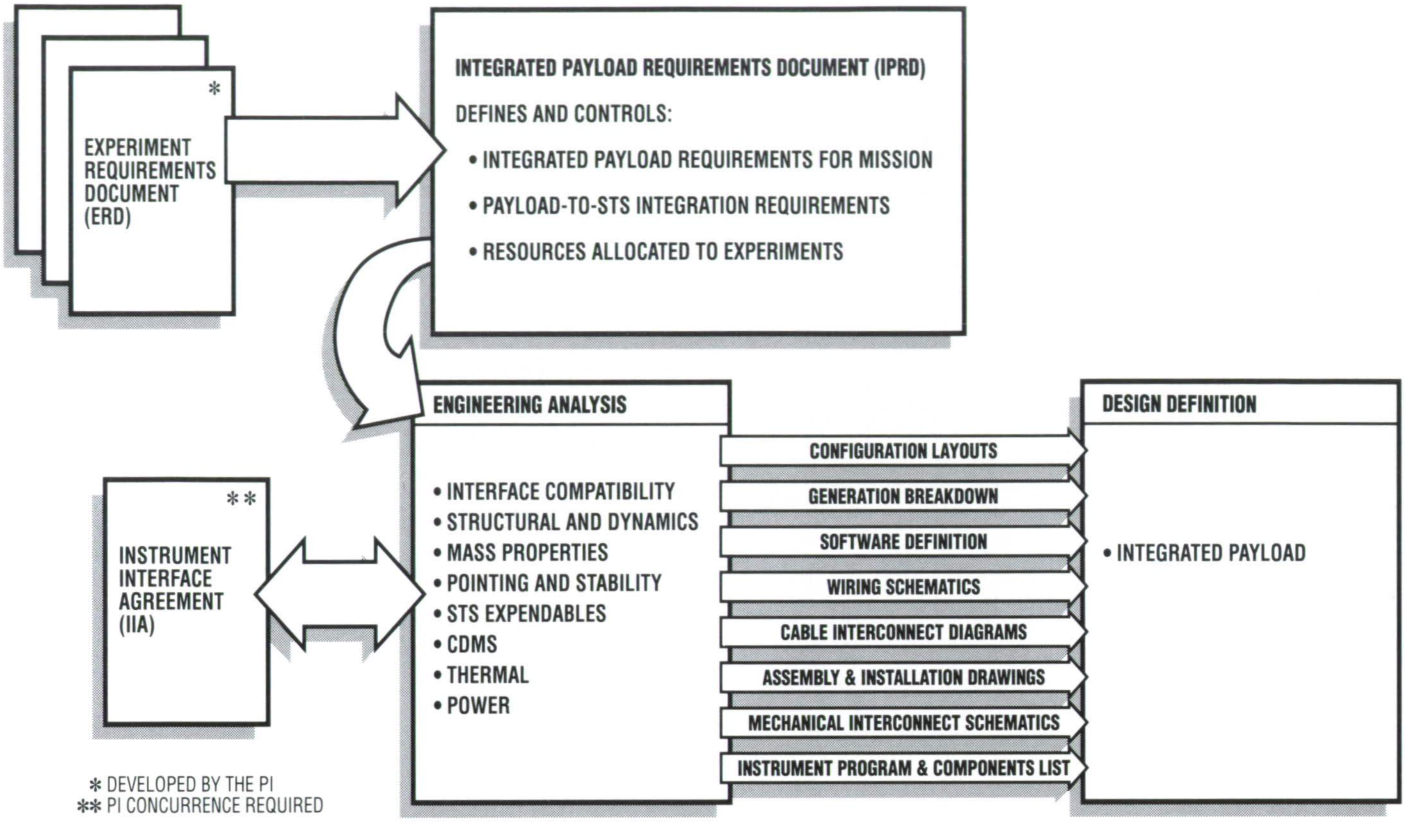
STS PAYLOAD INTEGRATION MANAGER (PIM)

- SHUTTLE/PAYLOAD COMPATIBILITY AND SAFETY CERTIFICATION
- FUNCTIONAL CHECKOUT
- FLIGHT OPERATIONS

LAUNCH SITE SUPPORT MANAGER (LSSM)

- INTERFACE COMPATIBILITY AND SAFETY VERIFICATION
- ACCEPTANCE TESTS
- PAYLOAD ASSEMBLY AND OPERATIONAL CHECKOUT

Integration Management Interfaces



Integrated Payload Mission System Design

The MROFIE

The payload integration process for all missions managed by MSFC is governed by JA-447, Mission Requirements on Facilities/Instruments/Experiments (MROFIE) for Space Transportation Systems (STS) Attached Payloads. This document, referred to as the MROFIE, presents the mission integration and operations process throughout the development phases of requirements definition, interface resolution, design, design verification, physical integration, and flight planning and implementation. It defines the respective responsibilities of the instrument developer and mission manager and specifies content and formats for data packages required for submittal in conjunction with major milestone reviews.

Using the requirements documents as an information source, the analytical integration team consolidates the experiment requirements with requirements of the host carrier elements, conflicts are resolved, and accommodations resources are allocated to experiments. At this point, an interface agreement is negotiated for each investigation in the mission, formalizing the interface and operations requirements to be met by both the investigator and the mission team. For MSFC Spacelab missions, interface and operations aspects are controlled by separate documents. An Instrument Interface Agreement (IIA) covers physical interface considerations, while an Operations and Integration Agreement (O&IA) covers ground and flight operations. For secondary payload missions managed by GSFC, the requirements document becomes the controlling document when concurrence is reached between the investigator and carrier project management. For JSC life sciences missions, the controlling document is the Project Interface Control Agreement (PICA). The PICA is developed by the mission management office to define those experiment requirements that are accommodated by the mission plus detailed experiment/Spacelab interfaces.

In designing and developing your instrument, you must adhere to the interfaces agreed to in the formal integration documents. This ensures that the mission manager can properly allocate accommodations required by each instrument/experiment, and it also results in a compatible integrated

payload. A formalized configuration management procedure is in effect at the time the interface agreements are baselined, and any changes are processed and incorporated according to these procedures.

Experiment Requirements Document (ERD)

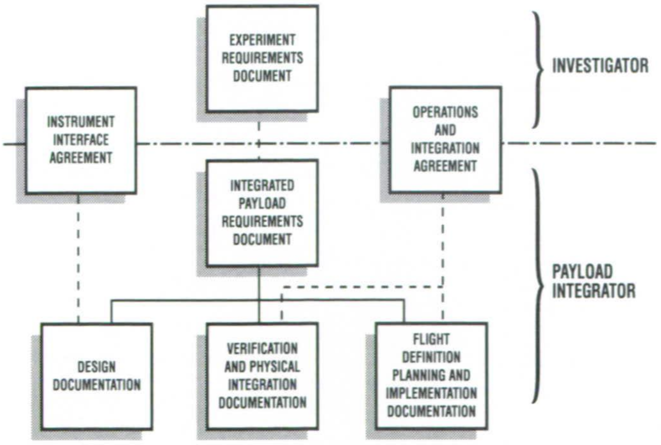
The Experiment Requirements Document (ERD) describes your experiment requirements in the following areas:

- Experiment operation and configuration
- Flight operations and environments
- Electrical requirements
- Thermal control/fluid requirements
- Data system and flight software requirements
- Physical integration
- Mission operations support
- Training.

The ERD is phased by level of detail to accommodate the concurrent development of the instrument hardware and the definition, design, and design evaluation of the payload. Updates may be submitted at several key points during the integration process to provide additional levels of detail on the instrument design as these levels are developed by the instrument developer and as they are needed by the payload integrator.

The Instrument Interface Agreement (IIA)

The Instrument Interface Agreement (IIA) document is used jointly by the mission manager and the instrument developer to establish, control, and define the detailed physical aspects of electrical, mechanical, and thermal interfaces between the instrument and carrier. Environmental, cleanliness, electromagnetic, mass property, and schedule requirements are included. An envelope drawing indicating maximum size, limits of motion, connector locations, and mounting arrangement is also part of the document. The interface agreements are prepared by the payload mission management and reviewed in detail with each investigator. Once you agree to the IIA, it becomes the controlling interface document.



Investigator to Payload Integrator Documentation Relationship

Instrument Interface Agreement Contents

- ***Instrument-to-Carrier System Interface***
  - *– Structural/Mechanical Interfaces*
  - *– Pointing/Stabilization and Alignment*
  - *– Electrical Power/CDMS and Cabling*
  - *– Environmental Control*
  - *– Special Environments*
- ***Summary of Hardware Responsibilities***

Operations and Integration Agreement Contents

- ***Functional Description***
  - *– Payload Element Hardware*
  - *– Deliverable Items List*
  - *– Instrument Operating Modes*
- ***Flight Operations and Support***
  - *– Functional Objectives*
  - *– POCC Services and Support*
  - *– CDMS Services Required*
  - *– Data Product Requirements*
  - *– Activity Timeline Inputs*
  - *– Training Requirements*
- ***Physical Integration***
  - *– Activity Flow*
  - *– Personnel Support Requirements*
  - *– KSC Support Requirements*
  - *– Contingency Planning*
- ***Procedure Inputs***
  - *– KSC Procedures*
  - *– POCC Procedures*
  - *– Onboard Flight Procedures*

The Operations and Integration Agreement (O&IA)

The Operations and Integration Agreement (O&IA) formalizes operational and software interfaces. All flight requirements including operation sequence, command loading, telemetry formats, timelines, data to be recorded and transferred to the experimenter, contingency plans, and on-orbit constraints are contained in the flight operations section. The ground operations section contains all requirements pertaining to integration operations at management center facilities during shipping, and at the launch site.

The STS Documentation System

The STS documentation system as represented by the Payload Integration Plan (PIP) and its annexes is used by the mission manager and STS managers to identify requirements and agree upon implementation for the integrated payload. The PIP is a top-level document that identifies mutual responsibilities, defines the technical baseline for implementation, establishes guidelines and constraints for integration and planning, and includes controlling schedules. It also addresses integration tasks, verification requirements, operational service requirements, and flight and ground safety. The PIP annexes contain more detailed technical requirements and data needed to configure both flight and ground systems and to implement integration functions as outlined in the PIP. Not all annexes

Payload Integration Plan (PIP) Annexes

Annex 1: Payload Data Package
Annex 2: Flight Planning
Annex 3: Data Requirements for Flight Operations
Annex 4: Orbiter Command and Data
Annex 5: Data Requirements for the Payload Operations Control Center
Annex 6: Crew Compartment
Annex 7: Training
Annex 8: Launch Site Support Plan
Annex 9: Payload Interface Verification Summary
Annex 10: Intravehicular Activity (IVA)
Annex 11: Extravehicular Activity (EVA)

are required for every payload. The PIP and its annexes are developed by STS management based on inputs from the payload mission manager. An Interface Control Document (ICD) for the mission payload defines detailed interface specifications. When agreed to and signed by both the mission manager and STS management, the PIP with its appropriate annexes and the ICD become the technical contract for the mission. These documents are the means by which the mission manager arranges for standard and optional STS services to meet your experiment requirements.

The Integration Reviews

For most payload projects, a series of formal program reviews is important for coordinating the payload integration process. Each review occurs at a natural transition point in the integration activities and has a specific purpose.

Those reviews in which investigator team attendance is recommended include the:

- Integrated Payload Requirements Review (IPL RR)
- Integrated Payload Preliminary Design Review (IPL PDR)
- Integrated Payload Critical Design Review (IPL CDR).

The extent and scope of these reviews depends on the complexity of the payload and the nature of specific issues.

In preparation for these reviews, you are sent a documentation package and asked to comment on those aspects of the documents that pertain to your instrument interfaces and operational requirements. Each error, inaccuracy, problem observed, or change required is documented by a written Review Item Discrepancy (RID). A RID is a formal notation that contains a description of the problem, recommendations, impact if recommendation is not implemented, and comments.

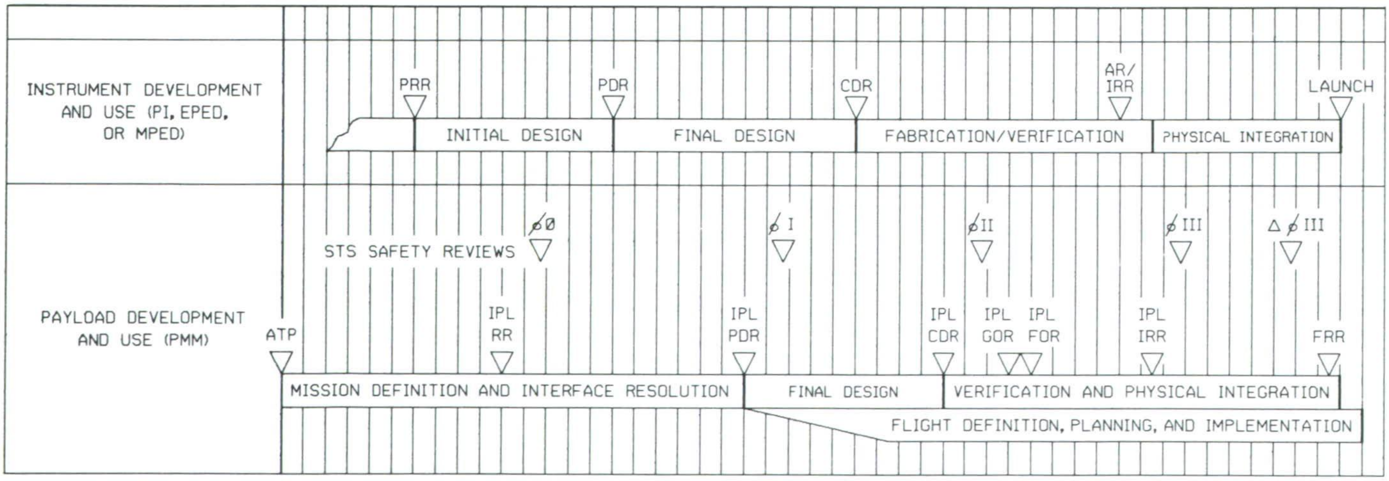
Integrated Payload Requirements Review (IPL RR)

As the payload project gets under way, the efforts of the integration team are directed toward defining the preliminary payload concept. The experiment requirements submitted by the investigators are integrated, consolidated and documented in the Integrated Payload Requirements Document (IPRD). At this point, the IPL RR is held to review this document along with associated layout and interface diagrams and schematics. As a result of this review, the mission manager allocates the available Space Shuttle resources to instruments and subsystem elements and officially controls these allocations. Official control requires you to inform the mission manager of any changes or potential changes to the allocation. Based on the comments to the data and resultant resolution from the review, the integration team begins preparation of the interface control agreements.

Some payload projects do not hold an IPL RR. The subjects are instead covered at the Integrated Payload Preliminary Design Review.

Integrated Payload Preliminary Design Review (IPL PDR)

This review is held to finalize the mission requirements, baseline the payload element design interfaces, finalize the safety verification methods and begin their implementation, and begin planning for physical integration, flight support, and payload crew training. To accomplish this, the PMM inte-



Typical Major Milestones for Payload Integration

grates the documentation resulting from the instrument PDRs and develops the necessary mission documentation. The baselining of instrument design interfaces as described in the interface control agreements is also accomplished in this time frame.

Integrated Payload Critical Design Review (IPL CDR)

This review is similar to the Integrated Payload Preliminary Design Review in scope and operational procedure. Its purpose is to review the final design against experiment requirements to verify payload compatibility with the STS and among the payload elements and to verify overall system safety. The physical integration and the flight definition, planning, and implementation documentation are available for review to ensure compatibility of this documentation and the final design.

Other Mission Reviews

Several other major reviews that do not require participation by the experiment team are conducted to prepare for physical integration and flight. These reviews are specified in the Payload Integration Plan, the overall control document, and involve the mission management and integration team, ground operations personnel from KSC, and flight operations personnel from JSC. These events include the Integrated Payload Ground Operations and Flight Operations Reviews, the Integration Readiness Review, and four or five Flight Safety Reviews and three Ground Safety Reviews in which investigator team members sometimes participate.

The Payloads System Safety Program

There are two distinct aspects of the payloads system safety program. Instrument developers are required to certify the safety of their payload equipment, including ground support equipment, to the mission manager. In turn, the mission manager must certify the safety of the integrated payload to the STS operators at the Johnson and Kennedy Centers.

The instrument developer is responsible for all activities required for safety certification of payload element equipment and operations. Safety assurance consists of three steps:

Hazard Identification: Payload flight and ground support equipment, along with its attendant flight and ground operations, are analyzed to determine potential hazards.

Hazard Control: A method is devised by which the hazard is controlled and/or eliminated. In certain cases, this may be accomplished by operating procedures.

Hazard Control Verification: The instrument developer demonstrates by test, analysis, or inspection that the hazard control method does control or eliminate the hazard.

The information from these steps is documented in "Hazard Reports" which are submitted with supporting data at the major instrument development reviews.

The development of safety compliance data is a significant element of your documentation effort. These data provide the basis for certifying that the experiment equipment complies with NSTS 1700.7 and KHB 1700.7 requirements. While

STS Payload Safety Process:

- ***Phase 0 -*** *Identify potential hazards and causes*
- ***Phase I -*** *Identify approaches to eliminate or control hazards, establish verification methods*
- ***Phase II -*** *Verify design, implement controls*
- ***Phase III -*** *Verify hardware as built, certify safety compliance, compile open item list*
- ***Delta Phase III -*** *Close out all open items*

PI/PED Activities:

- ***Conduct safety evaluation***
- ***Prepare hazard reports***
- ***Support reviews with safety data packages***
- ***Verify compliance, certify instrument safety***

safety verification activities are integrated with interface activities, safety data requirements are structured to permit the closure of safety and interface issues to be handled separately. In general, safety data packages must incorporate sufficient information to enable assessment of operations, hazards, causes, and controls. Specific data requirements can be found in the safety implementation guidelines documents.

Compatibility of the payload design with STS safety requirements is established through a series of formal reviews between the mission integration team and the STS Flight and Ground Safety Review Panel. The basic review process consists of Phase 0, I, II, III, and DIII reviews corresponding to the basic payload development milestones of conceptual design, preliminary design, final design, hardware delivery, and Level-I integration readiness. The number and depth of these reviews may be tailored to reflect payload complexity, design maturity, and low hazard potential.

The integration team in effect represents you at these reviews using safety data submitted by you. You may be called on to participate in safety panel review meetings if the mission manager needs support at the review.

▶Physical Integration

Physical integration involves hands-on assembly of the experiment complement, that is, building the integrated payload, installing the integrated payload onto the carrier, mating the carrier with the Spacelab subsystems (this step is required for Spacelab-type payloads only), and finally, installing the carrier or Spacelab in the Orbiter cargo bay. Physical integration is accomplished in the following phases:

- **Off-line Payload Operations (Pre-Level IV Integration)**
  Payload element final assembly and checkout by instrument developer
- **Experiment Integration (Level IV)**
  Payload installation onto the carrier and verification of interfaces
- **Spacelab Integration (Level III/II)**
  Complete Spacelab assembly with integrated payloads, systems test, and checkout
- **Orbiter Integration (Level I)**
  Installation of carrier or Spacelab into Orbiter cargo bay.

Off-line payload element operations may be carried out partly at the instrument developer's facility and partly at the KSC experiment processing facility. The other phases of physical integration are performed only at the KSC facilities.

Investigator Team Participation

You are responsible for all aspects of instrument performance and for the resultant data. In keeping with this philosophy for operating Space Shuttle experiments, you are expected to support the integration of your hardware and software into the STS and prepare your equipment for flight. You provide procedures in the O&IA or an equivalent document for interface tests, special tests, calibration, servicing, maintenance, handling, etc., to be conducted during preflight or postflight operations. You are also expected to conduct or participate in the operation of your equipment and to provide and operate any integration ground support equipment that augments existing capabilities at KSC. You must perform all maintenance, repair, and servicing required on your equipment and provide spare parts, special tools, etc. Finally, you are expected to support or conduct the postflight processing of your equipment, including return shipment. The mission manager provides the official interface with KSC for the performance of launch site functions for the integrated payload and for off-line support.

Payload Ground Operations Working Group (PGOWG)

The Payload Ground Operations Working Group (PGOWG) provides a forum for coordinating and resolving issues related to physical integration and testing (ground operations). PGOWG is formed by the Launch Site Support Manager a few months prior to the scheduled delivery of the experiment equipment to KSC. The meetings are held at KSC and are hosted by KSC personnel. Two or three of the meetings equally spaced throughout the year before launch are usually held. Subjects discussed include the formal levels of physical integration and testing, the investigators' need for support services and facilities, and pre-launch and postflight environmental protection of the payload.

Delivering Your Instrument

Your instrument and attendant integration ground support equipment can be delivered to KSC via air, sea, or land. In addition to major highways and an onsite rail spur, barge docks are located on the Banana River , and there is an international seaport of entry at Port Canaveral. Foreign and 1domestic shipments may be flown into the Orlando International Airport, about 1 hour from KSC by car. U. S. Customs Service can be provided at KSC or the Cape Canaveral Air Force Station landing facilities, if arrangements are made in advance.

The payload processing flow begins when your instrument and Instrument Ground Support Equipment (IGSE) arrive at the Operations and Checkout (O&C) Building in the KSC industrial area. The first step is receiving and inspection. KSC checks in your shipment and initially inspects it for any visible shipping damage. Responsibility for detailed inspection rests with the instrument owner when equipment is unpackaged and set up in an assigned laboratory in the O&C Building.

Laboratory space may be made available in the O&C Building on a preassigned basis. These are generally unequipped areas with only facility lights and power provided. Specialty laboratories are also available on a time-shared basis.

In the laboratory, you will be able to assemble, calibrate, and verify the operation of your instrument and its ground support equipment before beginning integration with other payload elements on your mission. Participation of KSC Quality Control personnel in these activities has proved to be beneficial in obtaining flight readiness certification and is available by prearrangement. During this preintegration phase, minor repairs are possible, and electrical and mechanical repair and fabrication facilities are available.

Storage space is available. There is ample outdoor storage, but you should recognize that the coastal environment is highly corrosive. Because indoor storage, especially that which is environmentally controlled, is extremely limited at KSC, it is essential that you identify storage requirements to your mission manager as early as possible.

During the laboratory preparation of your experiment, the flight carriers (Spacelab racks and pallets) are being readied for integration. This preparation includes staging as well as installation of mission-peculiar equipment necessary to support your payload during integration.

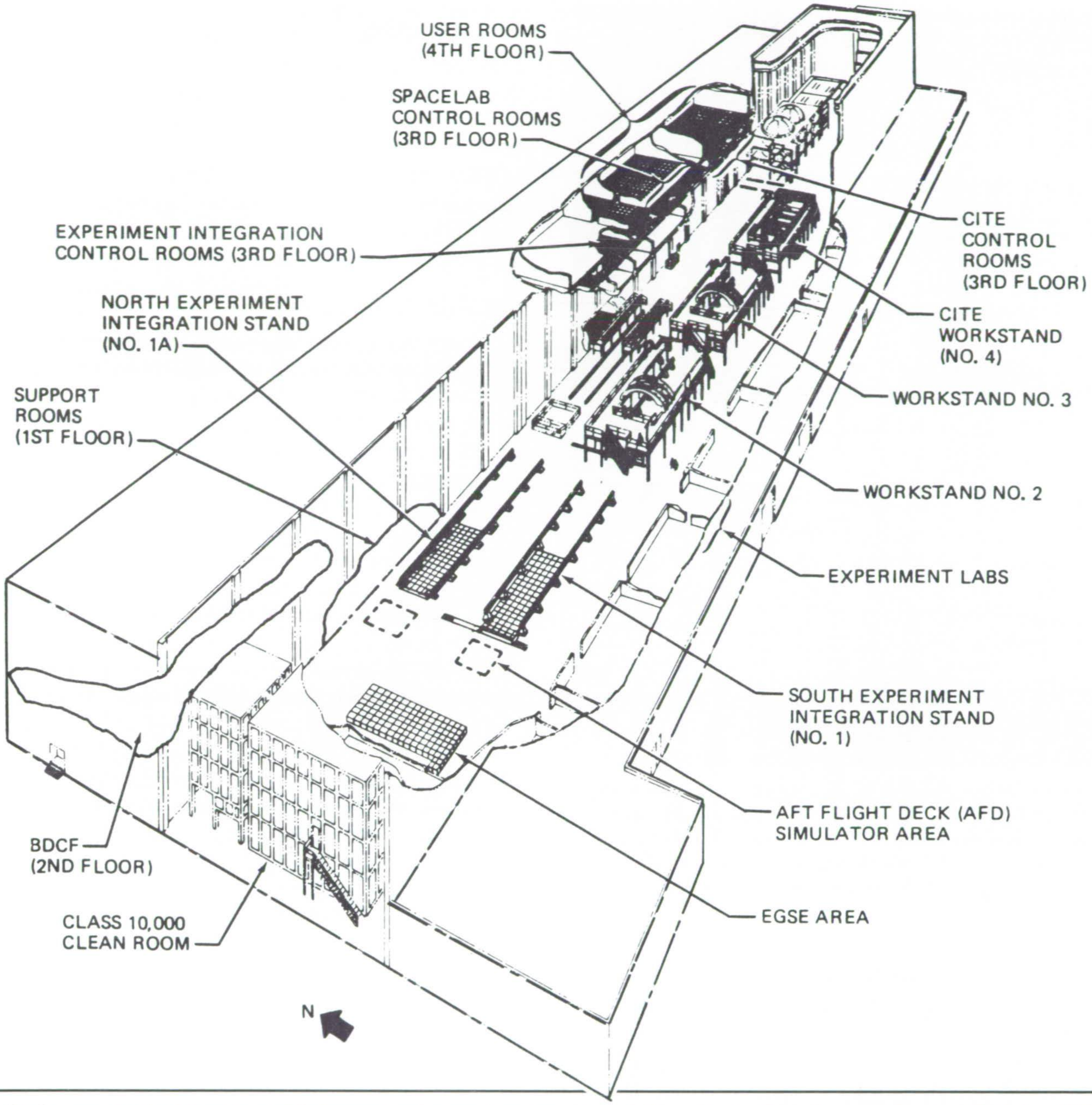
Installing the Instrument onto the Carrier

When staging and instrument preparation have been completed, KSC proceeds with installation of the individual instruments and makes the necessary mechanical, electrical, and fluid connections. This phase is referred to as experiment integration.

In addition to the laboratory space used for test and checkout, each instrument is assigned a dedicated area in one of the payload user rooms, if required. These user rooms are located on the fourth floor of the O&C Building and are outfitted to provide certain communication and data-handling services. By prearrangement, these services may be used to support experiment checkout and monitoring throughout the entire processing flow until launch.

Limited command capability from the user room to the Ground Support Equipment (GSE) can be prearranged. Equipment and services provided by NASA in the user rooms include cathode-ray tube and strip-chart recorder display capability for experiment data, Spacelab voice channel links, and a closed-circuit television monitoring system. If you have specialized checkout and/or data reduction equipment, there is reserved space and interface capability in the user room. Again, you need to identify any such equipment or the need for it to your mission manager as soon as possible. Limited user room capability also is available for non-Spacelab payloads.

During the experiment integration process, a team of specially trained KSC personnel conducts tests to verify the experiment interfaces. These test data are routed to your GSE in the user room for evaluation. Based on analysis of these



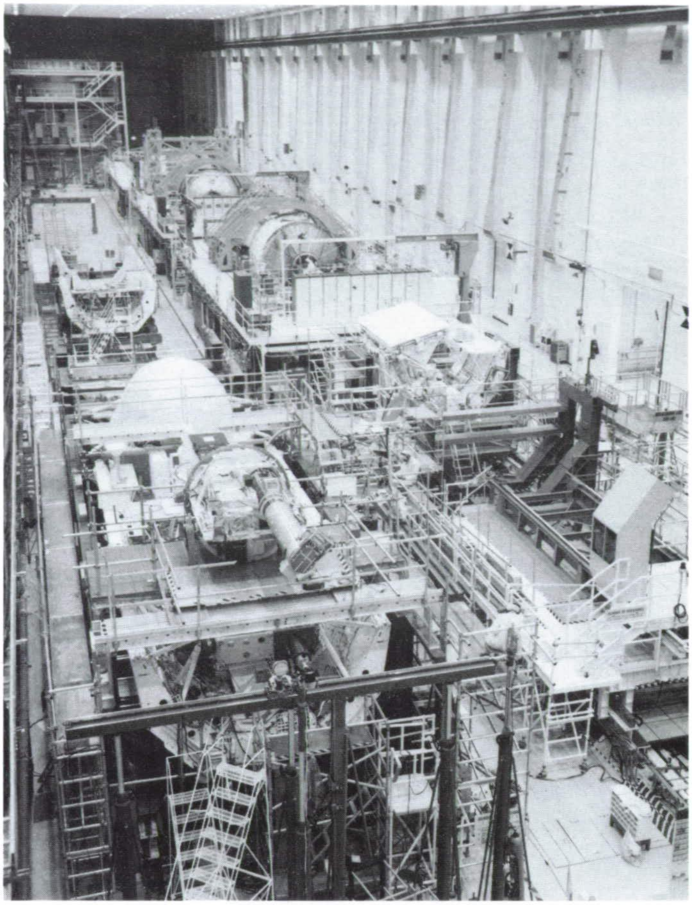
Payload processing begins when your instrument and support equipment are delivered to the Operations and Checkout Building at KSC. This building has several different work areas including rooms for user tests.

data, you are expected to confirm proper operation of your instrument. Details of the working relationship between you and the KSC test team are discussed at the planning meetings for your mission.

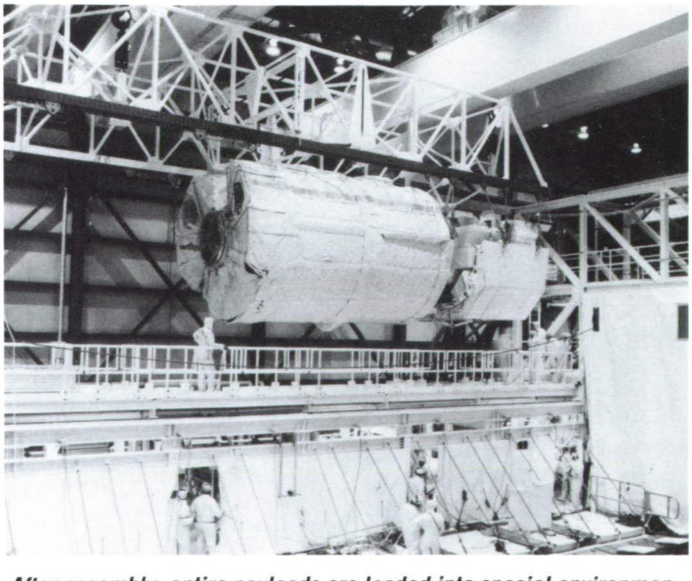
During experiment integration, as well as other stages of the integration process, the flight crew may serve as test operators on a pre-planned basis to develop proficiency, experience, and an understanding of integrated payload operations. The experiment integration area is equipped with an Orbiter aft flight deck simulation stand that provides mission specialist and payload specialist station mock-ups for crew training and operational verification of certain flight equipment.

Spacelab Integration

The Spacelab pallets and module rack sets that were assembled and tested during experiment integration are now moved into a workstand to begin an additional level of assembly referred to as Spacelab integration. This step involves bringing together all the pallets and racks and their support equipment to form a complete Spacelab payload. Typically, this occurs about 4 months prior to launch. (Note: This description of the processing flow assumes a combination module/pallet Spacelab mission; however, an igloo instrumentation container may replace the module and experiment racks on an all-pallet mission.)



Several payloads are always in various stages of assembly or disassembly in the Kennedy Space Center Operations and Checkout Building. The SL-2 payload is being integrated in the foreground. On the right, proceeding from front to rear, are the rack-door integration area, the OSTA-3 pallet, and the laboratory modules for SL-3 and -1.



After assembly, entire payloads are loaded into special environmentally controlled canisters and transported to another building for placement in the Shuttle.

Once the experiment racks are installed in the Spacelab module and the necessary pallet-to-pallet and pallet-to-module connections are made, a Spacelab integration test is performed to verify the new interfaces. During this test activity, you can monitor and analyze payload data from a user room, providing that such capability has been prearranged. Your activity on the workstand is very limited during Spacelab integration, but there may be provisions for hands-on work if the requirements are identified early in the experiment requirements documentation.

The Trip to the Launch Pad

At the end of the checkout process, a payload is loaded into an environmentally controlled canister that rides on a special transporter. From the O&C Building, a payload may take one of two routes. Spacelab payloads on dedicated flights are moved to the Orbiter Processing Facility (OPF) for loading into the cargo bay. Middeck and Get Away Special payloads also are installed in the OPF. They all ride inside the Orbiter as it moves through the Vertical Assembly Building, where the external tank and boosters are attached, and then to the launch pad. Nonhuman life sciences experiments are processed in a separate facility (Hangar L) and are integrated with the Spacelab either in the O&C Building, the OPF, or at the launch pad, as required. This represents the standard loading flow for a nondeployable payload such as Spacelab.

Payloads sharing the cargo bay with free-flyers move from the O&C Building to the Vertical Processing Facility (VPF). There they are stacked up with other cargo elements in a VPF workstand, and the combined cargo is loaded back into the canister. Then, the cargo is transported to the launch pad and installed into the Orbiter.

During this process, there are periods when there is no stand capability for thermal control, to power up, or to monitor payload elements. Once on the pad, active payload systems may be monitored through Shuttle systems, if this service is prearranged. Payload information gathered during this time is displayed at the Launch Processing System console in the Launch Control Center and in the O&C Building user room.

Once the Space Shuttle is delivered to the launch pad, a final launch readiness verification test is conducted. Time-critical life science or other experiments and specimens may be installed in the interior of the Spacelab module on the pad through the Orbiter middeck airlock and Spacelab transfer tunnel. Small experiments and equipment can be installed in the Orbiter middeck lockers up to 12 hours before launch.

Integration Schedules

The duration of the integration process depends, to a large degree, on the complexity of the resulting payload both from the standpoint of instrument-to-carrier interfaces as well as carrier-to-Orbiter interfaces. Payloads that have minimal reliance on the Orbiter data system and require the instrument developer to design to a fixed set of interfaces can be integrated relatively quickly. This class includes Get Away Special,

Complex Autonomous Payload, and the Hitchhiker carriers. For example, middeck payloads can be added to the Shuttle manifest as late as 7 months before launch although investigators should submit their requirements at least 22 months before launch. On the other hand, payloads based on Spacelab that require the development of mission-unique hardware and software plus extensive reconfiguration of carrier equipment from the previous flight need longer integration cycles.

From your point of view, two major milestones are significant for planning a flight experiment project. The first is when the preliminary experiment requirements need to be submitted. The second is when the hardware needs to be delivered to KSC. These milestones are commonly based upon the time from launch. ■

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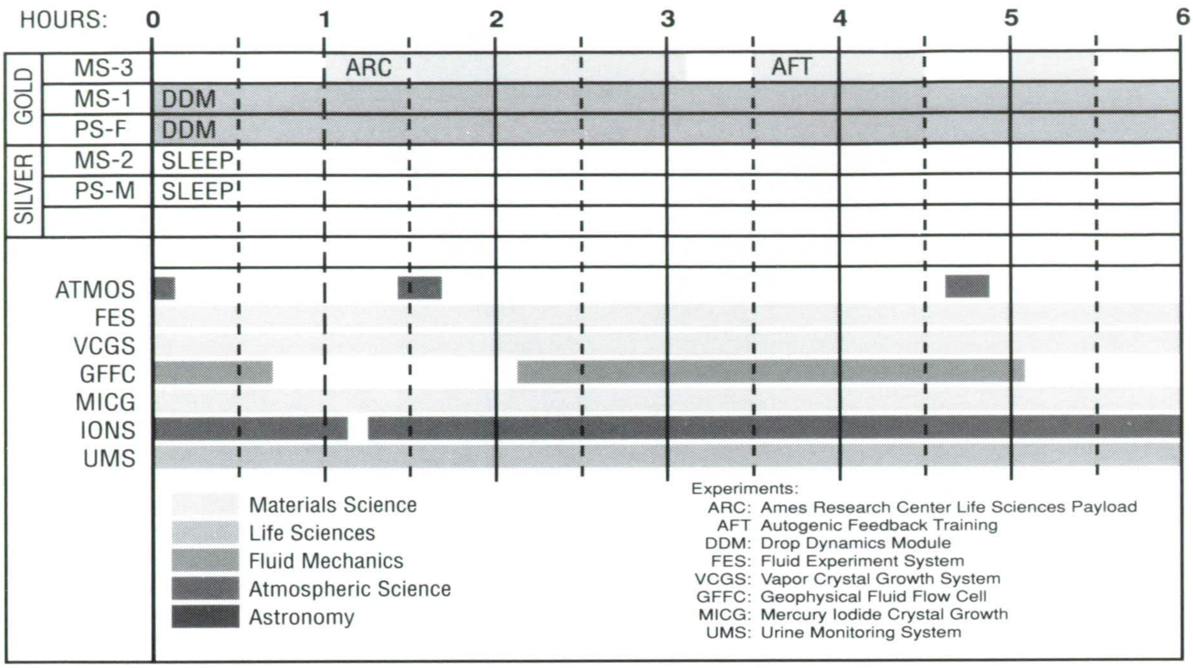
Flight Operations

ONCE A PAYLOAD IS IN ORBIT, every minute counts. To ensure that experiment activities on board the Shuttle and concurrent supporting activities on the ground flow smoothly, the actual flight is preceded by an extensive amount of planning and preparation. These preparations include the identification of flight and Payload Operations Control Center (POCC) operations requirements, the development of a detailed mission timeline, flight procedures development, flight crew and support personnel training, POCC configuration and ground support equipment setup, and contingency planning.

Flight operations planning and preparation is very much a part of the payload integration process. The nature of planning and preparation activities varies greatly with payload complexity, but the general flow is the same for all payloads. For Spacelab missions managed by the Marshall Space Flight Center (MSFC), you submit operations requirements as part of an Experiment Requirements Document (ERD). These requirements are incorporated into the mission Integrated Payload Requirements Document (IPRD) with the requirements of other experiments and host carrier elements. A detailed flight operations analysis is conducted in which conflicts are resolved and operating times and resources are allocated. Operations and Integration Agreements (O&IAs) are generated for your concurrence, and flight preparations proceed. You may also be required to develop flight and POCC procedures, assist with crew training, participate in simulations, and participate in or support real-time operations.



Sample Timeline Showing Crew Activities and Experiment Operations for Part of a Day

▶Mission Planning

Mission planning for integrated payload flight operations begins with the preliminary definition and analysis of individual experiment functional and resource requirements and culminates in the production of a nominal mission timeline, crew activity plan, and other flight definition data concerning targets, launch windows, attitudes, etc. These data are documented by the mission management organization as a Flight Definition Document (FDD). Onboard and POCC activities during real-time flight operations are ultimately scheduled according to this document after integration with STS planning.

Experiment Operations Flow

To facilitate mission planning, you are requested to describe the conduct of your onboard research activity in terms of functional objectives (FOs). A functional objective is any series or sequence of experiment operations that satisfies a specific scientific or engineering goal. It typically consists of a number of functional steps, such as activation, calibration, experiment operation, standby, and deactivation. Mission management uses your requirements to develop an experiment operations flow in which the functional objectives are ordered into a sequence beginning with experiment activation and proceeding through each step of the experiment until deactivation is complete. The experiment operations flow provides an outline of command assignments and related monitoring and verification functions that allow clear communication of functional operating requirements and interrelationships between functional elements.

Operations flows provide the framework for identifying and defining detailed operational requirements, including the following:

- Commands required for each experiment function
- Crew action/interaction
- Payload Operations Control Center action/interaction
- Operations verification requirements
- Special processing requirements (EGSE, POCC, offline)
- Sequential timing constraints
- Time required to perform functions.

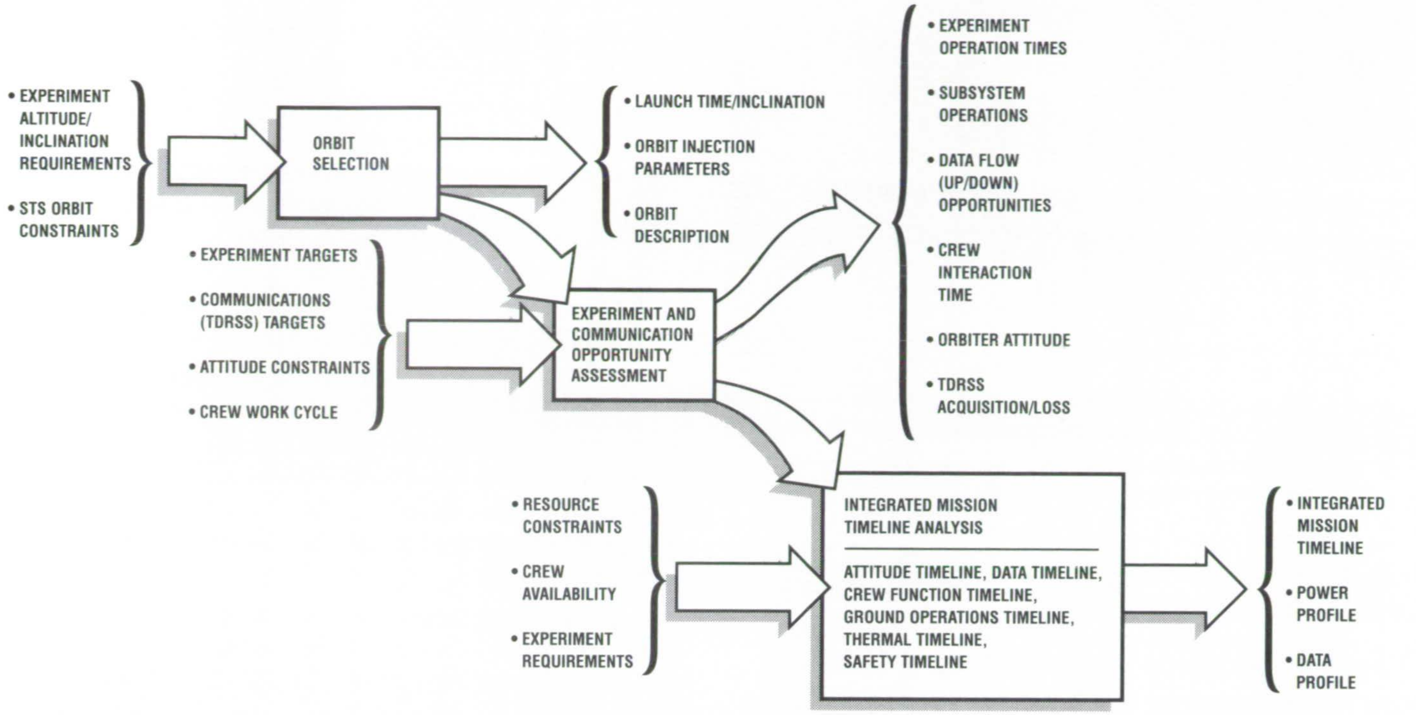
The experiment operations flow also is a basis for developing step-by-step crew procedures and for defining POCC operations tasks. It is essential to the documentation of experiment operations and therefore is a primary input to the flight operations section of the Operations and Integration Agreement.

Payload Flight Data File

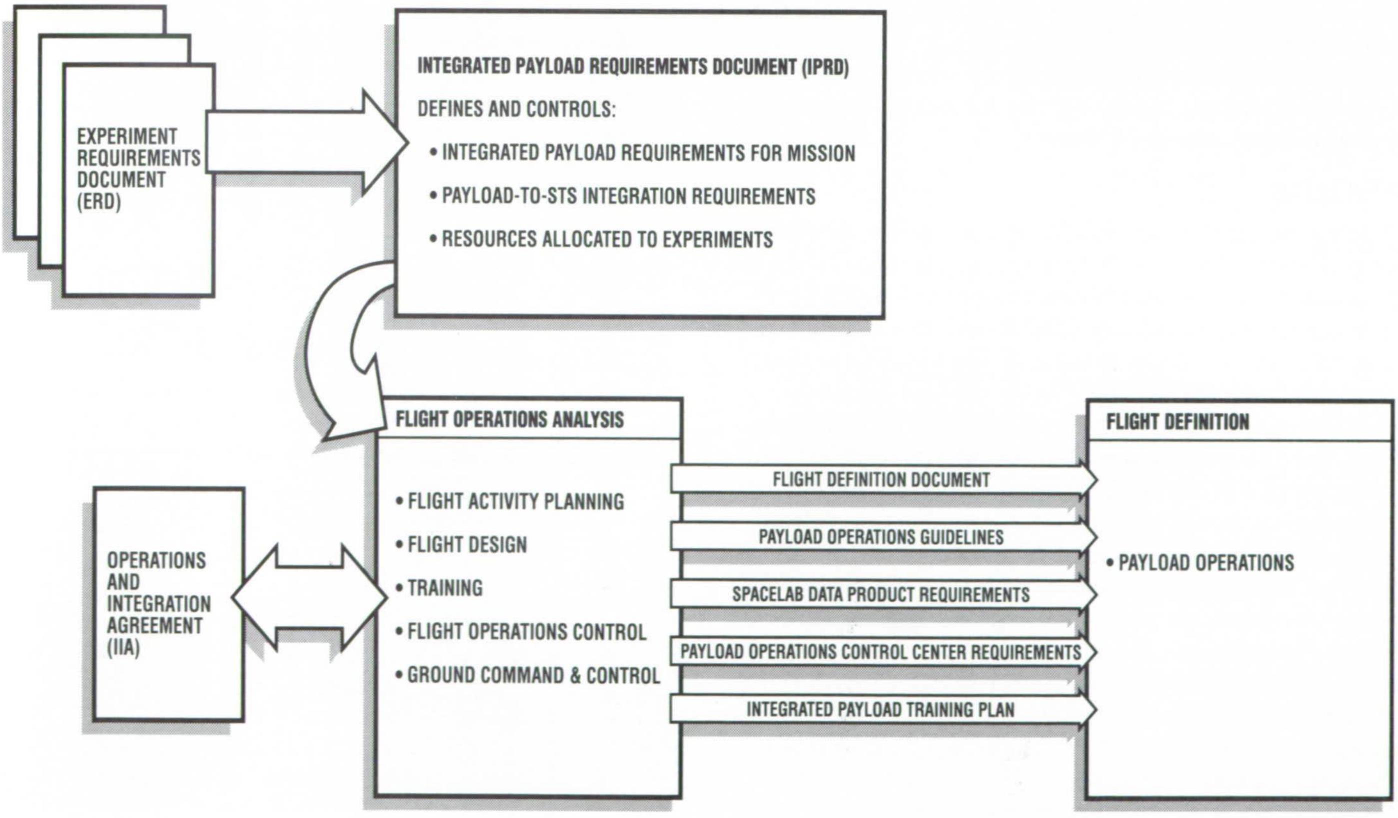
A payload flight data file is assembled for each mission. It contains procedures and reference material for each experiment and is stowed on board for use by the payload crew during the mission. Prior to the mission, it is an input to flight operations reviews and is used in payload crew training activities.

Investigators must provide mission management with experiment operating procedures and other reference data such as experiment maps, charts, and functional schematics to be included in the data file. Other items such as integrated payload procedures, the payload TV/Photo Operations Book, and stowage list are prepared by mission management.

The process of developing adequate procedures requires coordination among the payload crew, investigators, and flight operations engineers. Initial procedures are developed to satisfy crew functions defined in the experiment operations



Mission Design Flow



Integrated Payload Flight Definition/Planning/Implementation

The payload flight data file provides a ready reference for crewmembers as they work through experiment procedures.

flow described earlier. Procedures are finalized prior to experiment/payload physical integration and updated as required until launch.

Payload Operations Working Group (POWG)

The Payload Operations Working Group (POWG) provides a forum for coordinating the operational needs of the investigators with the Shuttle flight operations team at JSC. This group consists primarily of Principal Investigators, delegates of the Payload Mission Manager, flight payload specialists, and other personnel from the JSC Payload Operations Division. The group normally meets two or three times during the 12 months before launch. Subjects addressed include the investigators' needs for commands, telemetry, onboard services, monitoring facilities at mission control, and training for the flight crew and experiment monitoring teams.

▶Training

Training ensures that the payload crew and ground personnel are thoroughly familiar with their mission operations roles and work together as a team. Training requirements depend both on the complexity of the individual instruments and on the complexity of the integrated payload. The mission manager coordinates and schedules training for payload specialists, investigators, and other members of the payload flight operation team. You help determine training requirements for your instrument and participate in training the payload specialists and support personnel who may operate equipment, monitor data, or assist in troubleshooting from the ground control center. Also, all investigators who participate in POCC activities require indoctrination and training in POCC practices and equipment operation.

Payload crew training currently is conducted during a period beginning approximately midway through the payload integration cycle and continuing until launch. A goal for future missions is to limit the training period to 12 months or less. Training on individual experiments and instruments normally is scheduled prior to payload physical integration. Team training exercises generally are scheduled after completion of basic training on individual experiments.

Investigator participation in the payload crew training program includes the following:

- Define experiment training requirements including training windows and amount and type of training and communication requirements to mission management in time to permit integrated planning for training activities
- Plan, implement, execute, and assess payload crew training on individual experiments
- Support integrated experiment operations training during physical integration at KSC, experiment simulation training at the mission management center, and mission simulation exercises at the POCC.

You are responsible for providing the resources necessary for training at your home facility. Training resources may include classrooms, lesson materials, breadboard systems, and flight hardware as appropriate. The training curriculum is expected to cover:

- Familiarizing the crew with scientific objectives and the significance of research to be conducted
- Providing an understanding of experiment system and hardware functions and their importance to research objectives
- Developing proficiency in step-by-step experiment operation to the extent possible without STS/Spacelab supporting systems.

While at your facility, the payload crew also supports you in developing experiment operating procedures, in evaluating payload flight data file elements, and in evaluating human/systems compatibility (i.e., control and display layouts).

POCC training and familiarization are required so that experimenters may effectively use system resources and coordinate their activities with other POCC users. This training

Realistic training situations are an important part of flight operations preparation.

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begins with an overview conducted approximately 1 year before launch. Hands-on familiarization occurs about 6 months before launch. Simulations of on-orbit operations are conducted in the final months before launch.

▶The Payload Operations Control Center (POCC)

The Payload Operations Control Center (POCC) is the nerve center for payload flight operations. It contains facilities and system resources for monitoring, coordinating, and controlling payload on-orbit operations and for conducting preflight tests, verification, and simulations. You must define your requirements for using the POCC early in the mission cycle. These requirements are submitted as part of the Experiment Requirements Document (ERD).

In support of mission activities, you can expect to use facilities at one of several locations depending on the payload carrier and the needs of mission management. All NASA-managed Spacelab payloads are supported and controlled from the MSFC POCC, which offers a full range of communications and data system capabilities. The Attached Shuttle Payload Center at GSFC supports missions using Hitchhiker-G, Hitchhiker-M, and the Two-Axis Pointing System. Investigators with payloads in the Orbiter middeck can monitor experiment progress from the Customer Support Room associated with the Mission Control Center (MCC) at JSC. Finally, you have the additional option, under limited conditions, of operating out of your home facility by arranging for a communications link with the POCC. This is generally an optional service and requirements should be discussed with your mission manager because of implementation impacts.

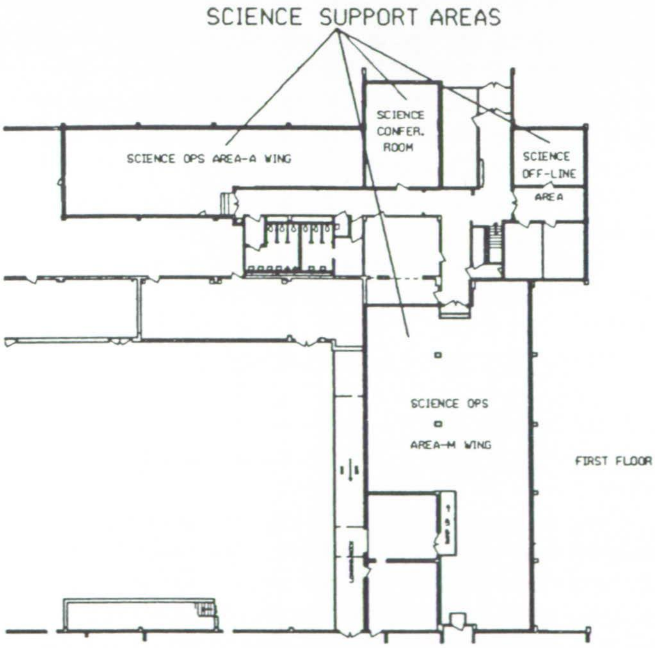
The mission management team is supported by a cadre of specialists who monitor experiment activities in the Payload Operations Control Center.

Facilities and Capabilities of the MSFC POCC

The MSFC POCC, part of the Huntsville Operations Support Center, contains areas designated for use by the mission management, payload operations, and investigator teams. All equipment and interfaces required for your activities are contained within the Science Support Area, which includes two Science Operations Areas (SOAs), a conference room, and an offline area. The operation areas are where POCC-provided workstations are located and where user-provided Ground Support Equipment (GSE) can be installed. POCC interfaces to your GSE are provided for transfer of digital, video, and analog data. With regard to other accommodations, a conference room is available to the investigator teams for formal and informal meetings, and the offline area provides an office-type environment for data analysis or other activities determined by mission management.

The POCC workstations provide you with a convenient means of monitoring experiment data streams and facilitate access to all required support systems and capabilities. Each workstation contains video monitors, a 48-button communications panel, computer terminals and printers, and other hardware or software required to gather, distribute, or record data.

POCC Data Flow: For Spacelab missions, the downlink telemetry inputs to the POCC include the high rate multiplexer experiment channels, the high rate multiplexer direct-access



Physical Layout of MSFC POCC User Area

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Investigator teams are responsible for defining the equipment needed to monitor experiments and analyze data in the Payload Operations Control Center.

channels, the Experiment Computer Input/Output (ECIO) channel, Subsystem Computer Input/Output (SCIO) channel, and STS data. Downlink video and analog data (including non-standard TV) are also available in the ground control center. The composite high rate multiplexer data stream is demultiplexed so that the output data are identical to the onboard inputs. The entire downlink system is therefore "transparent" to the user. The demultiplexed data may be routed either to the POCC standard processing and display equipment or to user-provided equipment. The experiment-dedicated data channels can also be made available to remote users. Specific data parameters can be selected by prearrangement for insertion into a near-real-time (NRT) data base. These data are then available for recall and display on POCC user terminals for up to 24 hours. After 24 hours, the data are available from tape, on special request.

Standard ground control center data processing services consist of calibration/engineering unit conversion, limit checking, data display, real-time or near-real-time playback, and experiment command. Data can be displayed on the CRT/hardcopy unit and stripchart recorders at your console, and high-speed printouts can be obtained from the POCC facility. The real-time or the near-real-time system may be accessed from the console terminal.

Using Experiment Ground Support Equipment (GSE): You may use your own special processing equipment in addition to the above POCC-provided services. Data sources available to experiment ground support equipment include any high rate multiplexer channel (dedicated or direct-access), experiment data on the ECIO channel (serialized output of investigator data contained in this channel), selected operational downlink parameters, 4.2-MHz analog, video, voice, and timing.

In general, an experimenter must provide a computer when off-line analysis is required. Although the POCC computer accepts user-supplied FORTRAN for limited real-time analysis, investigators wishing to use this service should develop such code at least 6 months prior to launch. Use of this capability is determined on a case-by-case basis due to POCC limitations.

Computer-compatible digital tapes normally are not provided by the POCC, so any investigator requirements for generation of such tapes during the mission must be satisfied by experiment ground support equipment. Computer-compatible digital tapes are available post-mission from the Spacelab Data Processing Facility at GSFC.

Experiment Commands: You may send commands to your own instrument from the POCC-provided terminal. Commands that may create compatibility problems—e.g., simultaneously turning on experiments that require high power—are restricted to the POCC Command Controller, who coordinates system usage among experimenters and the Mission Control Center (MCC). The command uplink system is a manual system requiring initiation of commands either singly or in sets of up to 30 individual commands. This system is shared with the MCC and is available only during satellite coverage.

What Happens During the Mission?

During the flight there are two distinct but interacting areas of responsibility that you need to keep in mind: Orbiter operations and payload operations.

The MCC at JSC is responsible for all Orbiter operations and for approving all payload operations that impact flight operations or safety. Investigators do not interact directly with MCC personnel.

POCC operations are coordinated jointly by the Mission Scientist and the Payload Operations Director (POD). The Mission Scientist, who chairs the Investigator Working Group, is responsible for all aspects of the science operations of the flight. The POD is responsible for the operation of the payload flight crew, the POCC, and the cadre that supports the investigators.

Astronomers review X-ray observation program during Spacelab 2.

The mission management team make real-time decisions about payload operations as the flight progresses.

Prior to flight, an operations timeline is developed and practiced during flight simulations. During the flight, you are responsible for conducting your own operations from the POCC (or a remote location) using control center terminals, experiment ground support equipment, or voice contact with the crew, in accordance with the planned mission operations. The POCC operates around the clock, so the need for multiple shifts of experiment operators is addressed and planned for by the Investigator Working Group.

It is likely that changes will be made to the planned operations timeline during flight. On Spacelab 2, extensive replanning was required early in the mission due to a lower orbit than intended and the failure of an instrument to respond to command. Modification of the planned timeline requires consideration of the impact on Orbiter operations, science operations, and crew activities. This usually requires at least one shift to accomplish. The Mission Scientist meets with the investigators to assess the impact on each experiment, and they reach a consensus on the modifications that should be made. Once a plan is adopted, the Mission Scientist, affected experimenters, and the POCC cadre work together to implement the changes. Investigator inputs play an important role in guiding the replanning effort. When the flight duration of Spacelab 1 was extended by 1 day while the mission was in progress, investigators developed a shopping list of experiments that they would like to have conducted with the extra time. This list, together with inputs from the crew, PI teams, and the POCC operations team, was used as a basis for replanning the final day.

The Mission Scientist can authorize implementation of changes that do not impact other experiments or Orbiter operations, so you can request changes in the operation of your equipment on a short time scale in response to results from the flight. Direct voice contact with the payload specialist also allows you to make real-time changes in the way the crew conducts your experiment, although this requires some discipline on each experimenter's part to avoid impacting other investigations. ■

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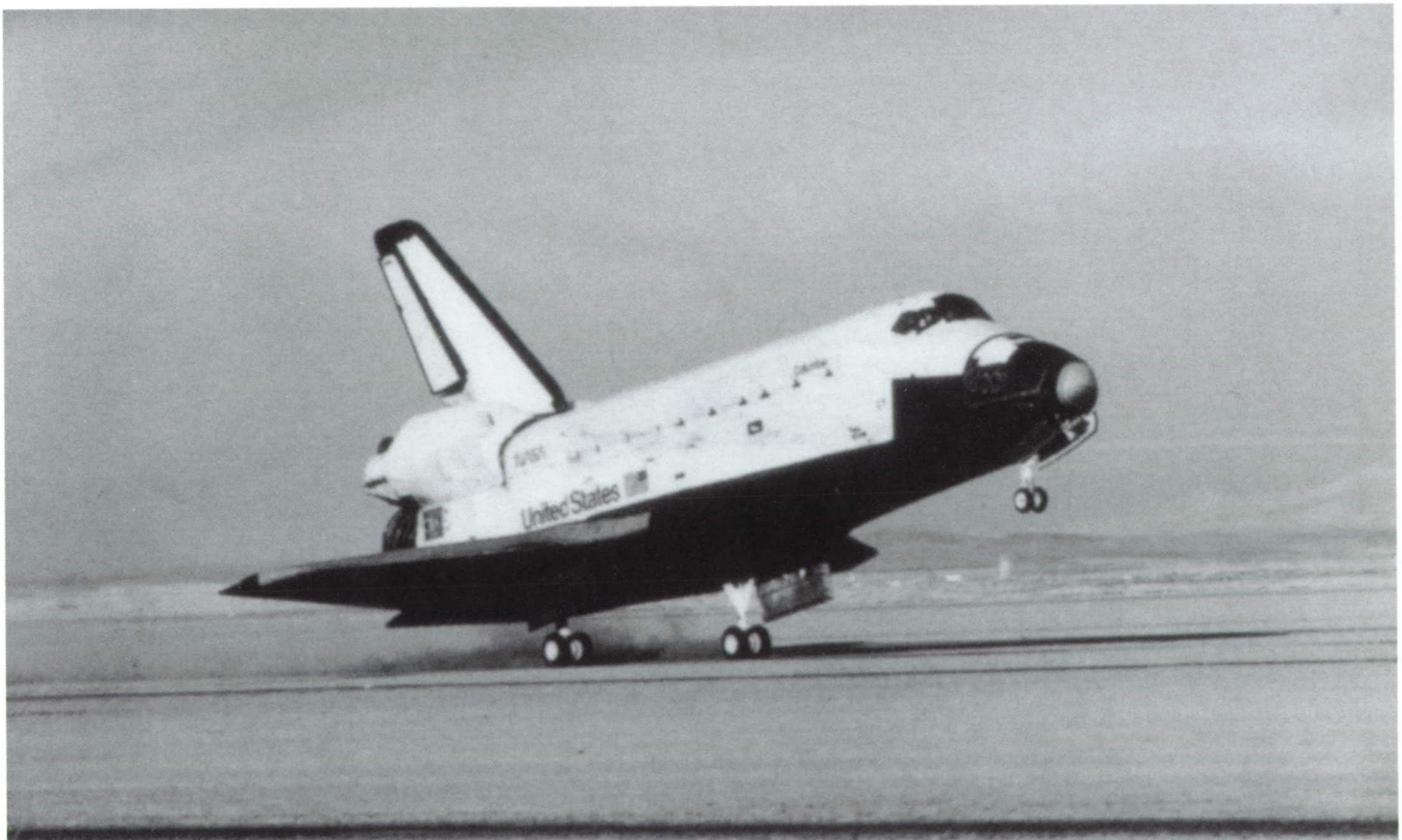


After the Shuttle lands, experiment equipment as well as crystals and other samples are removed and returned to the investigator or to the NASA hardware inventory.

8

Postflight Operations

ONCE THE ORBITER LANDS, the excitement of the mission gives way to the excitement of discovery. You know from the real-time telemetry or crew observations whether your instrument operated as planned. Your curiosity may have been further whetted by quick-look science data. At this point three steps remain: retrieval and analysis of the data or other products generated during the flight, return of the instrument hardware, and preparation of postflight reports.

▸Retrieval of Data and Products Stored on Board

The Shuttle currently lands at Edwards Air Force Base in California and is ferried to the Kennedy Space Center (KSC) on the back of a 747 jumbo jet. The capability to land the Shuttle at KSC directly from orbit has been demonstrated and is being considered for future missions.

Once runway operations have been completed, the Orbiter is towed to a secure area for safing and deservicing. Middeck payloads are normally removed 1 day after landing while other payloads remain in the Orbiter during the trip back to KSC. Ferry preparations are accomplished, and the Orbiter is loaded onto the carrier aircraft.

After arrival at KSC, the Shuttle is lifted from the transport plane and towed to the Orbiter Processing Facility (OPF) for payload removal. This process from landing at Edwards Air Force Base until arrival at the OPF takes about 6 days, and payload removal begins several days later. At the OPF large payloads such as Spacelab are placed into the canister/transporter for return to the Operations and Checkout (O&C) Building. There individual instruments are deintegrated from their carriers.

Within the Orbiter's postflight processing flow, there are various opportunities for quickly returning time-critical samples, film, and other experiment products to investigators. They entail special access to the Orbiter, however, and requirements should be discussed with your mission manager. Middeck payloads may be removed as early as 2 hours after landing. The Protein Crystal Growth experiment developed by the University of Alabama at Birmingham stowed samples in a battery-powered refrigerator. Within several hours of landing, the samples had been unloaded and were on their way back to Birmingham via private jet. Early removal of biological specimens from the Spacelab module may be accomplished about 5 hours after landing. Other time-critical items in the payload bay may be removed in the OPF. Materials processing samples flown in the Materials Science Laboratory (MSL) carrier in the payload bay were available about 2 days after the Orbiter was returned to KSC.

▸Processing of Telemetered Data

The capture, handling, and distribution of mission data products are accomplished through the combined efforts of the Goddard Center and the Johnson Center data-processing facilities. NASA has developed a high-capacity data-handling facility at GSFC for capturing and processing the Ku-band payload data streams and for generating science and ancillary data tapes for delivery to investigators. This facility, the Spacelab Data Processing Facility (SLDPF), can support both Spacelab and mixed cargo missions and serves as the post-mission distribution point for most downlink and ancillary data products. Processing, editing, and distributing of video

products, on the other hand, is handled by the Johnson Center; NASA's field sequential video format requires color conversion for most users and the converter is located at JSC.

The Ku-band communications link carries three data channels. The Operational Downlink (OD), carried on Ku-band Channel 1 (or the S-band system), includes voice and low-rate telemetry data. The telemetry stream contains Orbiter systems parameters (referred to as "ancillary" data), payload parameters from the Orbiter computer, and data frames from the Payload Data Interleaver (PDI). Channel 1 is transmitted from the Tracking and Data Relay Satellite System (TDRSS) ground station at White Sands, New Mexico, to the Mission Control Center (MCC) at JSC and to the Marshall Center. At JSC, selected ancillary and payload data are extracted and made available to remote Payload Operations Control Center (POCC) facilities in support of real-time payload operations. These data are also transmitted to the Goddard Center for post-mission processing and distribution to users and include an Orbiter Calibrated Ancillary System data set. Finally, the Johnson Center compiles ephemeris data from the NASA tracking system and furnishes GSFC with a Postflight Attitude and Trajectory History (PATH) data set when required.

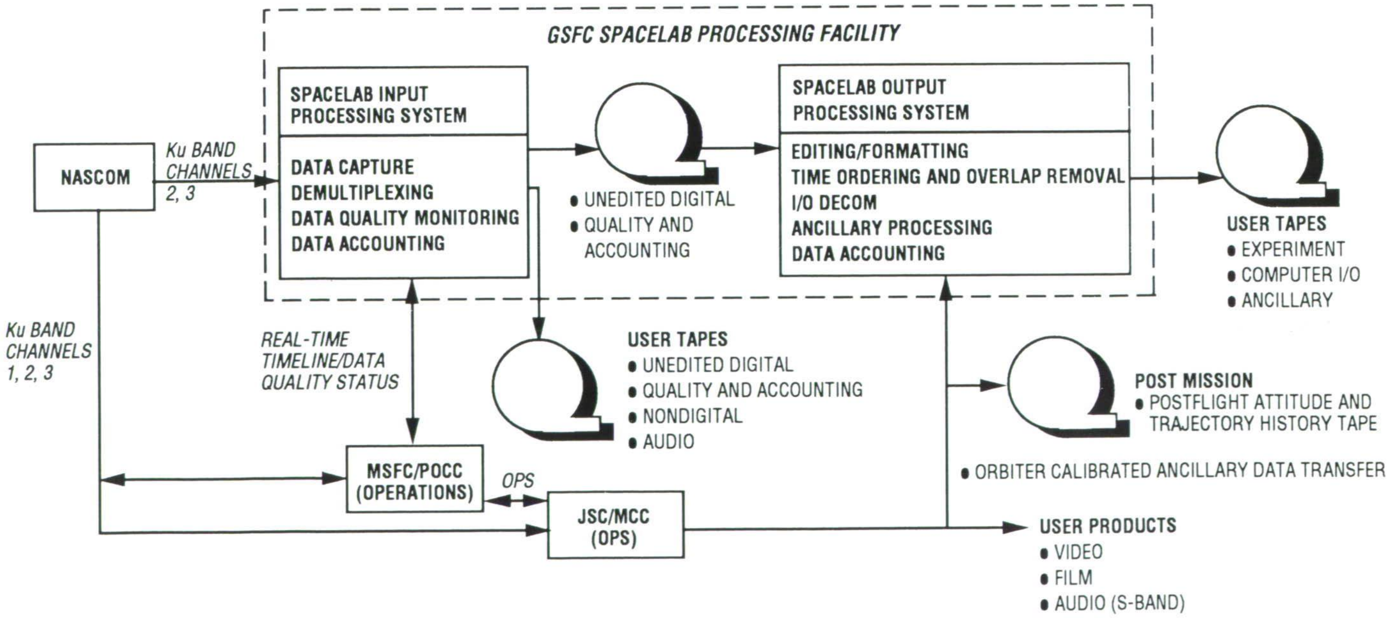
Ku-band Channels 2 and 3 are relayed to GSFC for capture and processing via and the Domestic Satellite (DOMSAT). Channel 2 has a data rate up to 2 Mbps, and Channel 3 has a rate of 2 to 50 Mbps. The complete processing flow occurs in two stages. The Spacelab Input Processing System performs demultiplexing, frame synchronization, quality monitoring, and data accounting. Digital data compatible with the Spacelab High Rate Multiplexer can be further processed by the Spacelab Output Processing System. This system performs time ordering, frame editing, quality checking, ancillary data processing, and formatting and generating output products.

Although the GSFC data processing facility was developed specifically to support Spacelab missions, its full capabilities can be applied to any payload data stream compatible with the high rate multiplexer format. On Spacelab missions, this includes all data gathered through the experiment computer data bus as well as dedicated experiment channel inputs to the High Rate Multiplexer (HRM). Users should be aware that data streams not compatible with the high rate multiplexer format can only be processed to the extent of capturing and reordering the data into the original time sequence. Such data cannot be edited and formatted.

Investigators normally request data products such as edited digital tapes containing experiment data, ancillary tapes, audio (voice) tapes, and wide-band analog data tapes. Ancillary data are not merged with experiment data on a single tape, but each tape contains time tags to assist in correlating data. The tapes are written according to requirements specified by the investigator during analytical integration of the mission. Digital data are available in a standard 1,600-bpi or 6,250-bpi, 9-track format.

The goal of the Spacelab Data Processing Facility (SLDPF) is to provide raw experiment digital data tapes (of 1 Mbps average data rate over a 168-hour mission operations period) within 30 days of each mission. Edited experiment digital data tapes with minor frame fill and overlap removal (of 500 kbps average data rate over a 168-hour mission operations period) should be available within 60 days after the mission. Higher average data rates and requirements for certain ancillary data products may result in longer delivery times.

Data tapes from the SLDPF are sent to the users as the tapes are written. The first processed data should be received



Data Processing Overview for Spacelab Missions

What will the Spacelab Data Processing Facility (SLDPF) Provide?

ITEM	DESCRIPTION
Audio Tapes	Contains selected voice data from the three voice channels for periods requested by the users.
Analog Tapes	Contains filtered wideband analog data
Instrumentation Data Tapes (IDT)	Contains selected High Data Demultiplexer (HRDM) output channels along with Spacelab Coordinated Universal Time
High-Density Tapes (HDT)	Contains the raw-captured Ku-band Channels 2 and/or 3 data
Spacelab Experiment Data Tapes (SEDT)	Contains blocked and unedited demultiplexed channel data from one or more dedicated experiment channels
Spacelab I/O Data Tapes (SIDT)	Contains blocked and unedited demultiplexed Experiment Computer (EC) I/O and Subsystem Computer (SC) I/O channel data
Spacelab Quality Control and Accounting Tapes (SQAT)	Contains quality and accounting information for specified SEDT and/or SIDT files
Spacelab Experiment Channel Tapes (SECT) experiment channel	Contains edited and formatted data from one dedicated
Spacelab I/O Channel Tapes (SICT)	Contains selected decommutated words from the ECIO and SCIO channels edited and formatted for individual experimenters
Spacelab Ancillary (SANC) Data Tapes	Contains documented guidance, navigation, and control (GN&C) words from the ECIO channel with related ancillary parameters. Also contains decommutated and converted housekeeping parameters from the ECIO and SCIO channels
Postflight Attitude and Trajectory History (PATH)	Contains postflight attitude and trajectory parameters computed in standard coordinate systems.
Spacelab Post-Mission Ancillary Tapes (SPMA)	Contains SANC data that have been merged with PATH data received from JSC
User Calibrated Ancillary Tapes	Contains selected Orbiter parameters calibrated and computed ephemeris and attitude data
Payload Data Interleaver (PDI) Tapes	Contains decommutated words from the Orbiter PDI data stream edited and formatted for individual experimenters

What Other Products are Provided?

Video Cassette Tapes	Experiment video scenes recorded as required by the experiment functional objectives
Photographic Films	Film products including 35-mm 70-mm, or 16-mm motion picture required by the experiment functional objectives
Spacelab Experiment Command History	Contains time-sequenced tabulation of commands entered onboard and downlinked via the ECIO channel
Other	Miscellaneous data items on a mission-specific basis

shortly after the mission ends. The goal is to distribute all data within 60 days of receipt. Reprocessing of unacceptable data should be completed within 90 days of the reprocessing request, if this request is received within 90 days after launch. Master tapes are archived for 12 months to ensure that all reprocessing requests can be fulfilled. After 12 months a decision is made whether to continue storing these tapes or to erase them for reuse. You are encouraged, therefore, to verify the completeness and quality of your data set at an early date (within 90 days after receipt) and provide a suitable long-term storage environment for your data products.

▶Hardware Retrieval

Payload deintegration is essentially the reverse of the integration process without the test and checkout requirements. Spacelab payloads first undergo deintegration in which the pallets, module, and igloo are uncoupled, and the rack and floor assemblies are removed from the module. Experiment hardware is then deintegrated from the racks, pallets, or other carrier structure. The time required to return experiment hardware to the developer depends on the complexity of the payload, ranging from a week for simple payloads to a month or more for complex, full cargo bay payloads, such as dedicated Spacelab flights.

After deintegration of the payload, experiment hardware is returned to the developer or, if appropriate, to the NASA inventory. Procedures for deintegration and return of experiment hardware are developed prior to flight. Instrument developers support, and possibly conduct, the deintegration of equipment and perform any postflight processing, including return shipping of their equipment.

▶Reports

The Postflight Report is prepared by the mission manager with input from the investigators. The investigator evaluates in-flight experiment operations, including a description of any problems encountered and their resolution, and the results of a quick-look analysis of the experiment scientific data. The latter are usually a summary of the data taken and an estimate of the quality of data expected to be received. Since the Postflight Report is required 60 days after flight, no detailed results are expected.

A final report to the office funding the investigation is required for NASA-sponsored investigations, typically 12 months after receipt of the total data set. This report includes the results of data analysis. If appropriate, submission of the raw and reduced data to a national data base is also required at this time.

Public release of data does not occur prior to the expiration of the investigator's proprietary time period; however, TV, motion picture footage, and still photographs are released to the news media by the NASA Public Affairs Offices as soon as possible after the mission. While this does not encroach on the proprietary nature of the investigator's scientific data, you should be aware of these Public Affairs releases in situations where your experiment activities are competition sensitive. ■

Notes:

Contacts

Research Sponsorship

Office of Space Science and Applications (OSSA)
NASA Headquarters
Washington, DC 20546

Life Sciences Division
Code EB
202-453-1530

Earth Science and Applications Division
Code EE
202-453-1706

Microgravity Sciences and Applications Division
Code EN
202-453-1490

Space Physics Division
Code ES
202-453-1676

Astrophysics Division
Code EZ
202-453-1437

Office of Aeronautics and Space Technology (OAST)
NASA Headquarters
Washington, DC 20546

Director for Space
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202-453-2733

Information Sciences and Human Factors Division
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202-453-2747

Materials and Structures Division
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202-453-2760

Flight Projects Division
Code RX
202-453-2835

Information on Mission Flight Opportunities – NASA Headquarters

Flight Systems Division
Code EM
NASA Headquarters
Washington, D.C. 20546
202-453-1560

Transportation Services Division
Code MC
NASA Headquarters
Washington, D.C. 20546
202-453-2347

Office of Commercial Programs
Code CC
NASA Headquarters
Washington, D.C. 20546
202-453-1890

International Affairs Office
Code XI
NASA Headquarters
Washington, D.C. 20546
202-453-8440

Information on Payload Accommodations – NASA Field Centers

Spacelab, MDM and EMP Pallets, MPESS - A/B
Payload Projects Office/Code JA01
Marshall Space Flight Center
Marshall Space Flight Center, AL 35812
205-544-5416

Hitchhiker-G, Hitchhiker-M, and CAP
Special Payloads Division/Code 741.2
Goddard Space Flight Center
Greenbelt, MD 20771
301-286-9090

Get Away Special (GAS)
Special Payloads Division/Code 740.3
Goddard Space Flight Center
Greenbelt, MD 20771
301-286-5633

Two-Axis Pointing System (TAPS)
Special Payloads Division/Code 740.4
Goddard Space Flight Center
Greenbelt, MD 20771
301-286-7166

Crew Utilization
Crew Integration Office/CA3
Johnson Space Center
Houston, TX 77058
713-483-5851

Spartan
Special Payloads Division/Code 740.1
Goddard Space Flight Center
Greenbelt, MD 20771
301-286-4968

Middeck Lockers and MAR
Customer Integration Office/TC4
Johnson Space Center
Houston, TX 77058
713-483-1158

Additional Information Sources

NASA/GSFC
Public Affairs Office
Goddard Space Flight Center
Greenbelt, MD 20771

NASA/JSC
Public Affairs Office/AP4
Johnson Space Center
Houston, TX 77058

NASA/KSC
Public Affairs Office/PA-PIB
John F. Kennedy Space Center
Kennedy Space Center, FL 32899

NASA/MSFC
Public Affairs Office/CA20
Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

Key Documents & References

Carrier Systems & Accommodations

Attached Shuttle Payload Carriers
Brochure Provided by NASA/GSFC

Get Away Special (GAS) Small Self-Contained Payloads Experimenter Handbook
NASA/GSFC

Hitchhiker Shuttle Payload of Opportunity Carrier Customer Accommodations and Requirements Specification
HHG-730-1503-04, NASA/GSFC

Spacelab Payload Accommodations Handbook (SPAH)
SLP/2104, NASA/MSFC

Spartan User's Guide for the Class 200 Carrier System
NASA/GSFC

The Shuttle

Orbiter Middeck Payload Provisions Handbook
JSC-16536

Space Shuttle System Payload Accommodations
JSC 07700, Vol. XIV

STS User Handbook
NASA Headquarters
Washington DC 20546

Safety Verification Requirements

Payload Flight Equipment Requirements for Safety-Critical Structures
MSFC JA-418

Payload Verification Requirements
NSTS 14046

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JSC 11123

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NSTS 1700.7

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KHB 1700.7

POCC Capabilities

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SL-PA-210

POCC Capabilities Document, Vol. 2 — MCC/Remote POCC Interface Capabilities Description
JSC 14433

Miscellaneous

"Flying a Scientific Experiment Aboard the Space Shuttle - A Perspective from the Viewpoint of the Experimenter,"
A Technical Paper by Warren Hypen
(NASA/LaRC)
and Joseph C. Casas
(Old Dominion University
Research Foundation, Norfolk, Virginia)

Payload Integration

Launch Site Accommodations Handbook for STS Payloads
NASA/KSC Document, K-STSM-14.1

Mission Requirements on Facilities/Instruments/Experiments for STS Attached Payloads (MROFIE)
MSFC JA-447

Payload Developer's Guide for Launch Site Operations
KSC IV 0018.0

User's Guide to Spacelab Payload Processing
Produced by Flight Systems Office
NASA/KSC, Florida 32899

Experiment Opportunities

Guide to the Life Sciences Flight Experiments Program
Produced by
NASA Life Sciences Flight Programs
Branch at NASA Headquarters
Washington, DC 20546

Microgravity Science and Applications — Experiment Apparatus and Facilities
Brochure produced by
NASA/MSFC Marshall Space
Flight Center, AL 35812

Notes:

Abbreviations & Acronyms

A & I – Assembly and Installation
ACS – Attitude Control System
AFD – Aft Flight Deck
AFT – Autogenic Feedback Training
AO – Announcement of Opportunity
APC – Autonomous Payload Controller
ARC – Ames Research Center
ARINC – Aeronautical Radio, Inc.
AR/IRR – Acceptance Review/Integration Readiness Review
BK7 – Borosilicate Crown
CAP – Complex Autonomous Payload
CCAFS – Cape Canaveral Air Force Station
CCTV – Closed Circuit Television
CDMS – Command and Data Management System
CDR – Critical Design Review
Co–I – Co-Investigator
COSMIC – Computer Software Management and Information Center
CPR – Customer Payload Requirements
CRT – Cathode Ray Tube
D&PS – Design and Performance Specification
DDCU – Data Display and Control Unit
DDM – Drop Dynamics Module
DDS – Data Display System
DOMSAT – Domestic Satellite
DW-SFMDM – Dual Wide-Smart Flexible MDM
EAC – Experiment Apparatus Container
EC – Experiment Computer
ECAS – Experiment Computer Applications Software
ECE – Experiment Checkout Equipment
ECIO – Experiment Computer Input/Output
ECOS – Experiment Computer Operating System
ECS – Environment Control System
EMC – Electromagnetic Compatibility
EMI – Electromagnetic Interference
EMP – Enhanced MDM Pallet
EPDB – Experiment Power Distribution Box
EPE – Experiment Payload Element
EPED – Experiment Payload Element Developer
EPSP – Experiment Power Switching Panel
ERD – Experiment Requirements Document
ESA – European Space Agency
ETR – Experiment Tape Recorder
EVA – Extravehicular Activity
FDD – Flight Definition Document
FES – Fluid Experiment System
FMDM – Flexible Multiplexer/Demultiplexer
FO – Functional Objective
fwd – forward
GAS – Get Away Special
GFFC – Geophysical Fluid Flow Cell
GIRD – Ground Integration Requirements Document
GMT – Greenwich Mean Time
GN&C – Guidance, Navigation, and Control
GPC – General Purpose Computer
GRiD – GRiD Systems Corporation
GSE – Ground Support Equipment
GSFC – Goddard Space Flight Center
GSOC – German Space Operations Center
HDRR – High Data Rate Recorder
HDT – High Density Tapes
HRDM – High Rate Demultiplexer
HRM – High Rate Multiplexer
ICD – Interface Control Document
IDT – Instrumentation Data Tapes
IGI – Industrial Guest Investigator
IGSE – Instrument Ground Support Equipment
IIA – Instrument Interface Agreement
IMU – Inertial Measurement Unit
I/O – Input/Output
IPL – Integrated Payload
IPOTP – Integrated Payload Operations Training Plan
IPRD – Integrated Payload Requirements Document
IPS – Instrument Pointing System
IRIG–B – Interrange Instrumentation Group B
IVA – Intravehicular Activity
IWG – Investigator Working Group
JEA – Joint Endeavor Agreement
JSC – Johnson Space Center
KSC – Kennedy Space Center
KuSP – Ku–Band Signal Processor
LaRC – Langley Research Center
LDEF – Long Duration Exposure Facility
LeRC – Lewis Research Center
LSLE – Life Sciences Laboratory Equipment
LSSM – Launch Site Support Manager
MAR – Middeck Accommodations Rack
MCC – Mission Control Center
MCDS – Multifunctional CRT Display System
MDA – Motorized Door Assembly
MDM – Multiplexer/Demultiplexer
MET – Mission Elapsed Time
MICG – Mercury Iodide Crystal Growth
MIUL – Materials Identification & Usage List
MMU – Manned Maneuvering Unit Mass Memory Unit
MPE – Mission Peculiar Equipment
MPESS – Multi-Purpose Experiment Support Structure
MROFIE – Mission Requirements on Facilities/Instruments/Experiments
MSFC – Marshall Space Flight Center
MSL – Materials Science Laboratory
MTU – Master Timing Unit
MUA – Materials Usage Agreement
NASA – National Aeronautics and Space Administration
NASCOM – NASA Communications Network
NRT – near real time
NSP – Network Signal Processor
NSTS – National Space Transportation System
O&C – Operations and Checkout
O&IA – Operations and Integration Agreement
OAST – Office of Aeronautics and Space Technology
OCP – Office of Commercial Programs
OD – Operational Downlink
OPF – Orbiter Processing Facility
OR – Operational Recorder
OSSA – Office of Space Science and Applications
PAR – Payload Accommodation Requirements
PATH – Postflight Attitude and Trajectory History
PCA – Payload Clamp Assembly
PCB – Power Control Box
PCMMU – Pulse Code Modulation Master Unit
PDI – Payload Data Interleaver
PDR – Preliminary Design Review
PDSS – Payload Development Support System
PED – Payload Element Developer
PGOWG – Payload Ground Operations Working Group
PI – Payload Interrogator Principal Investigator
PICA – Project Interface Control Agreement
PIM – Payload Integration Manager
PIP – Payload Integration Plan
PMM – Payload Mission Manager
POCC – Payload Operations Control Center
POD – Payload Operations Director
POWG – Payload Operations Working Group
PR – Payload Recorder
PRR – Preliminary Requirements Review
PSP – Payload Signal Processor
RAU – Remote Acquisition Unit
REM – Release Engage Mechanism
RF – radio frequency
RID – Review Item Discrepancy
RMS – Remote Manipulator System
SAMS – Space Acceleration Measurement System
SANC – Spacelab Ancillary Data Tape
SC – Subsystem Computer
SCIO – Subsystem Computer Input/Output
SCU – System Control Unit
SDMU – Serial Data Management Unit
SECT – Spacelab Experiment Channel Tapes
SEDT – Spacelab Experiment Data Tape
SEID – Spacelab Experiment Interface Device
SICT – Spacelab I/O Channel Tapes
SIDT – Spacelab I/O Data Tape
SLDPF – Spacelab Data Processing Facility
SMCH – Standard Mixed Cargo Harness
SMIDEX – Spacelab Middeck Experiment
SOA – Science Operations Areas
SPAH – Spacelab Payload Accommodations Handbook
SPMA – Spacelab Post-Mission Ancillary Tapes
SPS – Spacelab Pallet System
SSP – Standard Switch Panel
SQAT – Spacelab Quality Control and Accounting Tapes
STS – Space Transportation System
T/L – Timeline
TAPS – Two-Axis Pointing System
TDRS – Tracking and Data Relay Satellite
TDRSS – Tracking and Data Relay Satellite System
TEA – Technical Exchange Agreement
TV – television
UCS – User Clock Signal
UMS – Urine Monitoring System
USMP – United States Microgravity Payload
VAA – Viewport Adapter Assembly
VCGS – Vapour Crystal Growth System
VPF – Vertical Processing Facility

Glossary

The following definitions are terms used throughout the document and are provided here for the convenience of the reader to minimize the ambiguity that is often present in the multiple use of specialized technical terms.

Attached Payload:

Payload which remains in the payload bay and is not deployed on orbit.

Cargo:

The total complement of payloads (one or more) or any one flight. It includes everything contained in the Orbiter payload bay plus other equipment, hardware, and consumables located elsewhere in the Orbiter that are user-unique and are not carried as part of the basic Orbiter payload support.

Dedicated Mission:

A mission which, because of size, weight, or other considerations, is devoted to the needs of a single STS customer.

Detached Payload:

A payload which is deployed from the Orbiter payload bay on orbit.

Experiment:

The science or application activities that are conducted through the use of instruments or facilities carried in the Orbiter.

Experiment Integration:

Often referred to as Level IV integration. Consists of installation and assembly of experiment equipment into Spacelab mounting elements (e.g., rack or pallet segment), mating the assemblies with certain Spacelab subsystems, and performing payload element and integrated testing.

Facility:

Hardware designed for performance of multiple experiments and reflight. Performance of the experiments may require additional experiment instrument hardware or may be accomplished by operation of the basic facility in a prescribed operation or sequence to meet a given experiment's objectives. A facility may be provided by the Government and utilized by several Principal Investigators.

Instrument:

Hardware designed to accomplish a limited number of experiments or investigations. The instrument is usually furnished by a Principal Investigator.

Instrument Ground Support Equipment (IGSE):

Sometimes referred to as Experiment Checkout Equipment (ECE). It is the ground support equipment supplied as a part of the payload element.

Integration:

A combination of activities and processes to assemble payload and STS components, subsystems, and system elements into a desired configuration and to verify compatibility among them.

Mission:

The performance of a coherent set of investigations or operations in space to achieve program goals. A single mission might require more than one flight, or more than one mission might be accomplished on a single flight. However, the terms "mission" and "flight" are frequently used interchangeably to denote those activities accomplished in space within the duration of a single flight.

Mission Peculiar Equipment (MPE):

Hardware/software supplied by a mission manager to adapt instruments/experiments to Spacelab or Orbiter interfaces.

Mission Specialist:

This NASA astronaut is responsible for coordination of overall payload/STS interaction and, during the payload operations phase, directs the allocation of the STS and crew resources to the accomplishment of the combined payload objectives.

Mixed Cargo:

Cargo containing more than one type of payload (for instance, cargo consisting of a Spacelab Pallet, MPESS structure, and Free-Flyer).

Orbiter Integration:

Often referred to as Level I integration and consists of mating the integrated Spacelab/Payload with the Orbiter, verification of new interfaces, assembly of the Orbiter with other Shuttle elements, and final preparations for launch.

Off-Line

Activities performed by or for a mission manager or payload element developer in areas other than the integration areas and which normally do not involve Spacelab hardware.

On-Line:

Activities performed by or in support of the Kennedy Space Center in the integration areas. On-line activities normally begin with the mating of payload elements with Spacelab hardware.

Payload:

A total complement of hardware/software elements assembled into an integrated cargo element.

Payload Bay:

The unpressurized midpart of the Orbiter fuselage behind the cabin aft bulkhead where most payloads are carried.

Payload Carrier:

Standard flight hardware and resident flight software for interfacing instruments or experiment equipment with the Orbiter. Carriers facilitate payload changeout and tailor resource interfaces to user needs.

Payload Element:

Hardware/software supplied by or through a Payload Mission Manager including Mission Peculiar Equipment, instruments, experiments, flight experiment facilities, and ground support equipment associated with the flight equipment.

Payload Element Developer (PED):

An individual or organization responsible for the development, fabrication, delivery, and performance verification of a payload element (may also be referred to as Mission Integrator, Mission Peculiar Equipment Developer, or Experiment Payload Element Developer).

Payload Mission Integrator:

Organization responsible for the resolution of the equipment and functional interfaces between the payload element (instrument/experiment) and the payload carrier/STS, under the direction of the Mission Manager.

Payload Mission Manager (PMM):

The individual assigned the responsibility for the integrated design and performance of a group of payload elements.

Payload Specialist:

This crewmember, who may or may not be a career astronaut, is responsible for the operation and management of the experiments or other payload elements that are assigned to him or her and for the achievement of their objectives. The payload specialist is an expert in experiment design and operation.

Principal Investigator (PI):

The scientist who is responsible for the conception and implementation of an experiment.

Spacelab Integration:

Often referred to as Level III/II integration. Consists of mating the integrated racks and pallet segments with the remainder of the Spacelab subsystems, verification of the new interfaces, overall system check, and an abbreviated mission simulation.

Space Transportation System:

An integrated system consisting of the Space Shuttle (Orbiter, external tank, solid rocket booster, and flight kits), upper stages, Spacelab, and any associated flight hardware and software.

Staging:

The assembly of the Spacelab equipment and/or its required Mission Peculiar Equipment prior to experiment integration onto the carrier.

User:

An organization or individual requiring the services of the Space Transportation System and its carrier systems.

Notes:

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NASA
National Aeronautics and
Space Administration
Marshall Space Flight Center